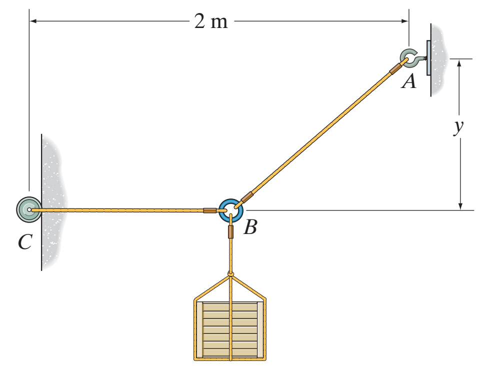
•3–1. Determine the force in each cord for equilibrium of the 200-kg crate. Cord BC remains horizontal due to the roller at C, and AB has a length of 1.5 m. Set $y = 0.75$ m.



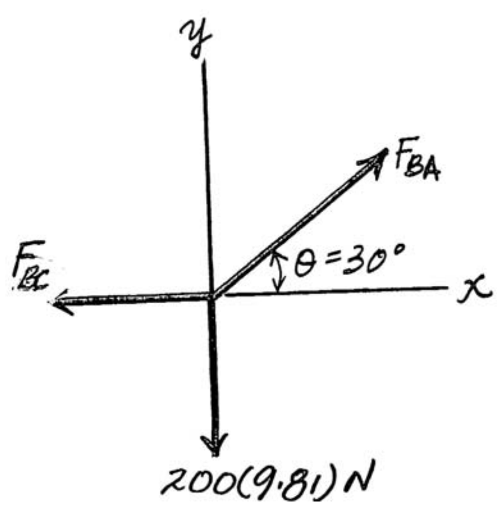
Geometry: From the geometry of the figure,

$$\theta = \sin^{-1}\left(\frac{0.75}{1.5}\right) = 30°$$

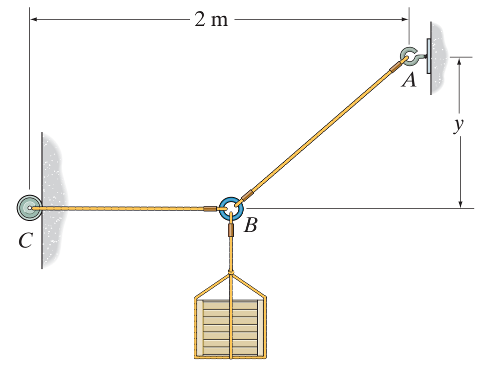
Equations of Equilibrium: Applying the equations of equilibrium to the free - body diagram in Fig. (a),

$+\uparrow \Sigma F_y = 0;$ $F_{BA} \sin 30° - 200(9.81) = 0$ $F_{BA} = 3924 \text{ N} = 3.92 \text{ kN}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $3924 \cos 30° - F_{BC} = 0$ $F_{BC} = 3398.28 \text{ N} = 3.40 \text{ kN}$ **Ans.**



3–2. If the 1.5-m-long cord *AB* can withstand a maximum force of 3500 N, determine the force in cord *BC* and the distance *y* so that the 200-kg crate can be supported.

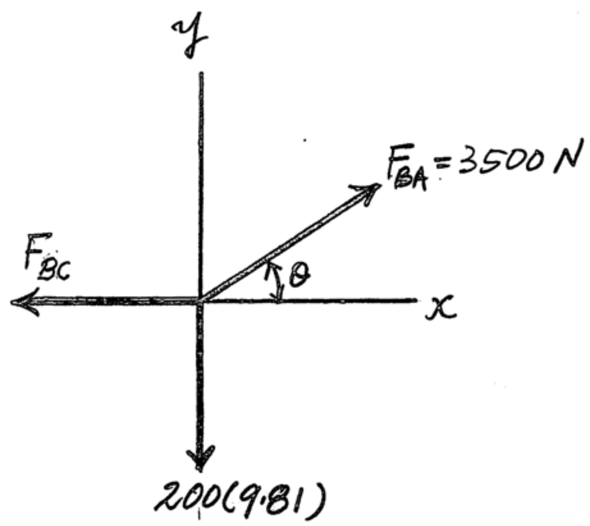


Equations of Equilibrium: Applying the equations of equilibrium along the *x* and *y* axes to the free - body diagram in Fig. (*a*),

$+\uparrow \Sigma F_y = 0; \quad 3500 \sin\theta - 200(9.81) = 0 \quad \theta = 34.10°$

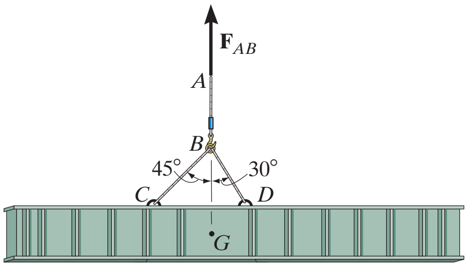
$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 3500 \cos 34.10° - F_{BC} = 0 \quad F_{BC} = 2898.37 \text{ N} = 2.90 \text{ kN}$ **Ans.**

$y = 1.5 \sin 34.10° = 0.841 \text{ m} = 841 \text{ mm}$ **Ans.**



(a)

3–3. If the mass of the girder is 3 Mg and its center of mass is located at point G, determine the tension developed in cables AB, BC, and BD for equilibrium.



Equations of Equilibrium: The girder is suspended from cable AB. In order to meet the conditions of equilibrium the tensile force developed in cable AB must be equal to the weight of the girder. Thus,

$$F_{AB} = 3000(9.81) = 29\,430\text{ N} = 29.43\text{ kN} = 29.4\text{ kN} \qquad \textbf{Ans.}$$

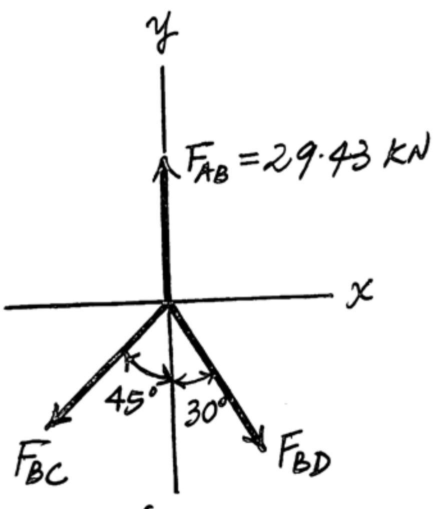
Applying the equations of equilibrium along the x and y axes to the free - body diagram in Fig. (a),

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{BD}\sin 30° - F_{BC}\sin 45° = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad 29.43 - F_{BD}\cos 30° - F_{BC}\cos 45° = 0 \qquad (2)$$

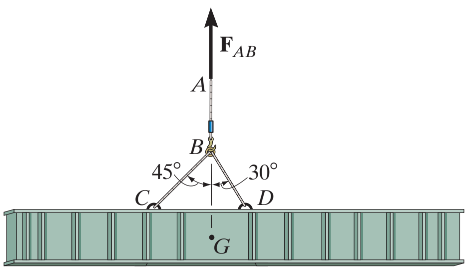
Solving Eqs. (1) and (2), yields

$$F_{BC} = 15.2\text{ kN} \qquad F_{BD} = 21.5\text{ kN} \qquad \textbf{Ans.}$$



(a)

***3–4.** If cables *BD* and *BC* can withstand a maximum tensile force of 20 kN, determine the maximum mass of the girder that can be suspended from cable *AB* so that neither cable will fail. The center of mass of the girder is located at point *G*.



Equations of Equilibrium: The girder is suspended from cable *AB*. In order to meet the conditions of equilibrium the tensile force developed in cable *AB* must be equal to the weight of the girder. Thus,

$F_{AB} = m(9.81) = 9.81m$ **Ans.**

Applying the equations of equilibrium along the x and y axes to the free-body diagram in Fig. (*a*),

$\overset{+}{\rightarrow}\Sigma F_x = 0;\quad F_{BD}\sin 30° - F_{BC}\sin 45° = 0$

$F_{BD} = 1.4142F_{BC}$ (1)

$+\uparrow\Sigma F_y = 0;\quad 9.81m - F_{BD}\cos 30° - F_{BC}\cos 45° = 0$ (2)

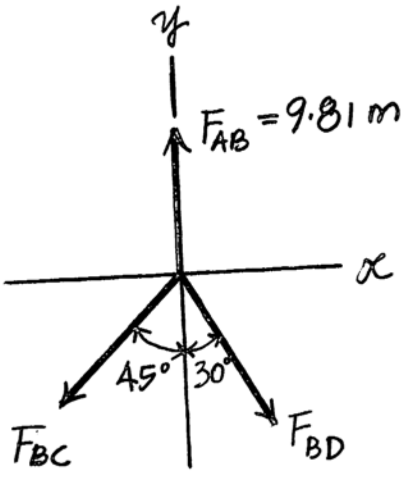
Since $F_{BD} > F_{BC}$, cable *BD* will break before cable *BC*. Substituting $F_{BD} = 20\ 000$ N into Eq. (1),

$F_{BC} = 14\ 142.14$ N

Substituting this result into Eq. (2), yields

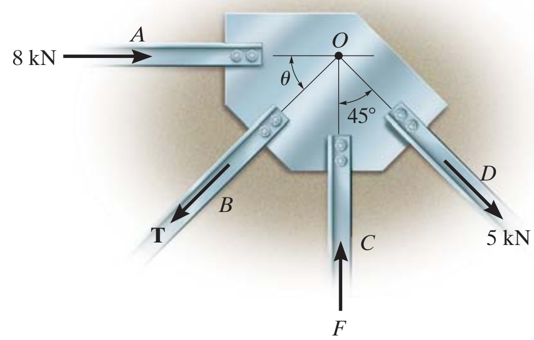
$9.81m - 20\ 000\cos 30° - 14\ 142.14\cos 45° = 0$

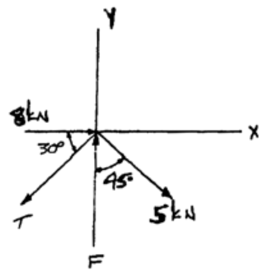
$m = 2\ 785\text{ kg} = 2.78\text{ Mg}$ **Ans.**



(a)

•3–5. The members of a truss are connected to the gusset plate. If the forces are concurrent at point O, determine the magnitudes of **F** and **T** for equilibrium. Take $\theta = 30°$.





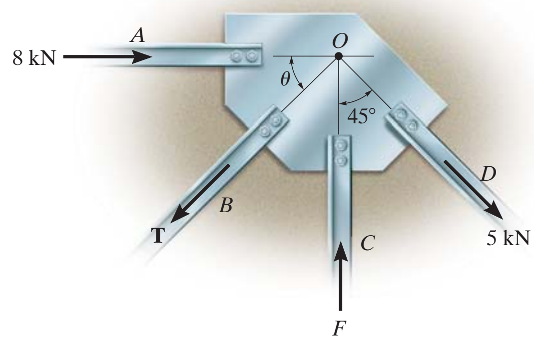
$\xrightarrow{+} \Sigma F_x = 0; \quad -T\cos 30° + 8 + 5\sin 45° = 0$

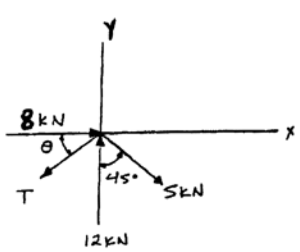
$T = 13.32 = 13.3\text{ kN}$ **Ans**

$+\uparrow \Sigma F_y = 0; \quad F - 13.32\sin 30° - 5\cos 45° = 0$

$F = 10.2\text{ kN}$ **Ans**

3–6. The gusset plate is subjected to the forces of four members. Determine the force in member B and its proper orientation θ for equilibrium. The forces are concurrent at point O. Take $F = 12$ kN.





$\xrightarrow{+} \Sigma F_x = 0; \quad 8 - T\cos\theta + 5\sin 45° = 0$

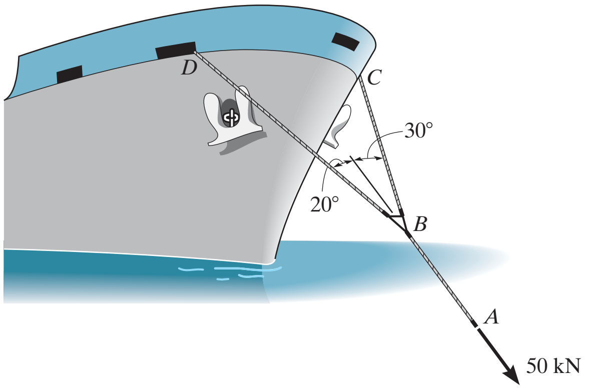
$+\uparrow \Sigma F_y = 0; \quad 12 - T\sin\theta - 5\cos 45° = 0$

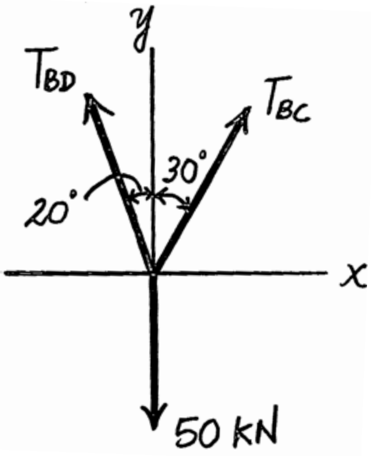
Solving,

$T = 14.3\text{ kN}$ **Ans**

$\theta = 36.3°$ **Ans**

3–7. The towing pendant *AB* is subjected to the force of 50 kN exerted by a tugboat. Determine the force in each of the bridles, *BC* and *BD*, if the ship is moving forward with constant velocity.





$\xrightarrow{+} \Sigma F_x = 0;\quad T_{BC} \sin 30° - T_{BD} \sin 20° = 0$

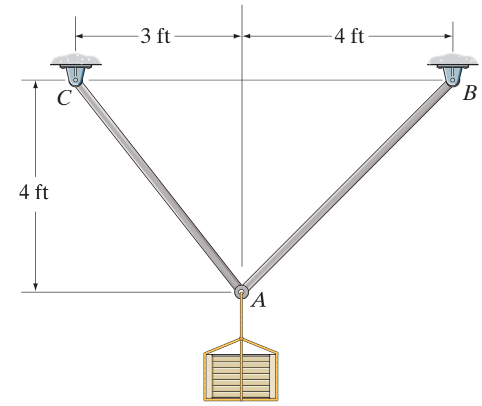
$+\uparrow \Sigma F_y = 0;\quad T_{BC} \cos 30° + T_{BD} \cos 20° - 50 = 0$

Solving,

$T_{BC} = 22.3\text{ kN}$ **Ans**

$T_{BD} = 32.6\text{ kN}$ **Ans**

***3–8.** Members *AC* and *AB* support the 300-lb crate. Determine the tensile force developed in each member.



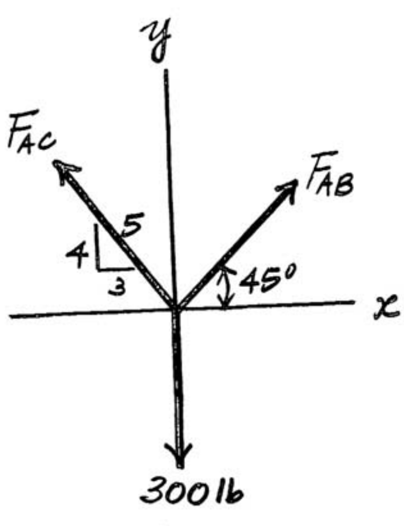
Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free - body diagram in Fig. (a),

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{AB}\cos 45° - F_{AC}\left(\frac{3}{5}\right) = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{AB}\sin 45° + F_{AC}\left(\frac{4}{5}\right) - 300 = 0 \qquad (2)$$

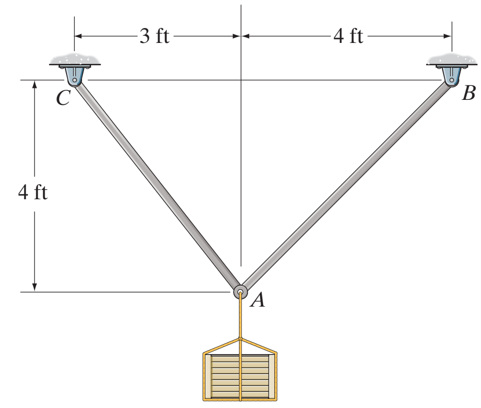
Solving Eqs. (1) and (2), yields

$F_{AC} = 214$ lb $\qquad F_{AB} = 182$ lb **Ans.**



(a)

•**3–9.** If members *AC* and *AB* can support a maximum tension of 300 lb and 250 lb, respectively, determine the largest weight of the crate that can be safely supported.



Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free - body diagram in Fig. (a),

$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{AB} \cos 45° - F_{AC}\left(\frac{3}{5}\right) = 0 \qquad (1)$$

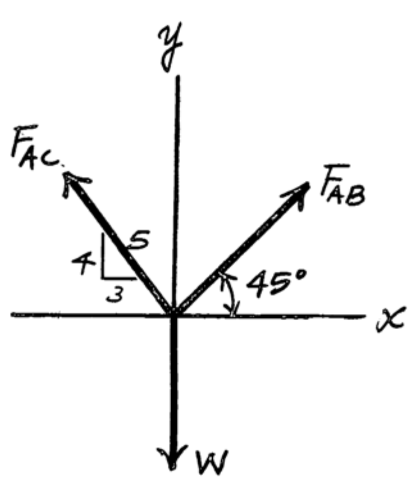
$$+\uparrow \Sigma F_y = 0; \qquad F_{AB} \sin 45° + F_{AC}\left(\frac{4}{5}\right) - W = 0 \qquad (2)$$

Assuming that rod *AB* will break first, $F_{AB} = 250$ lb. Substituting this value into Eqs. (1) and (2),

$F_{AC} = 294.63$ lb

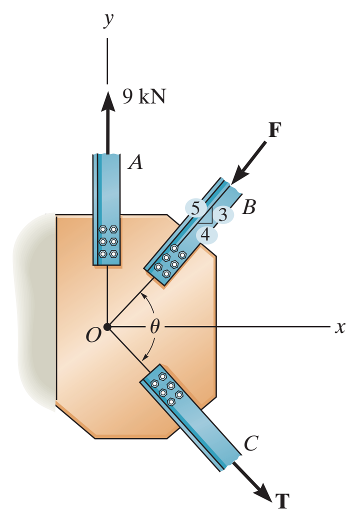
$W = 412$ lb **Ans.**

Since $F_{AC} = 294.63\text{ lb} < 300$ lb, rod *AC* will not break as assumed.



(a)

3–10. The members of a truss are connected to the gusset plate. If the forces are concurrent at point O, determine the magnitudes of **F** and **T** for equilibrium. Take $\theta = 90°$.



$\phi = 90° - \tan^{-1}\left(\frac{3}{4}\right) = 53.13°$

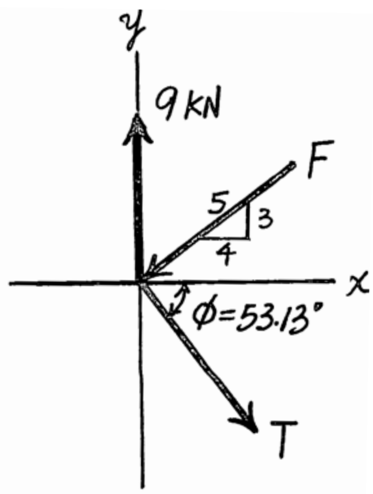
$\xrightarrow{+} \Sigma F_x = 0; \quad T\cos 53.13° - F\left(\frac{4}{5}\right) = 0$

$+\uparrow \Sigma F_y = 0; \quad 9 - T\sin 53.13° - F\left(\frac{3}{5}\right) = 0$

Solving,

$T = 7.20 \text{ kN}$ **Ans**

$F = 5.40 \text{ kN}$ **Ans**



3–11. The gusset plate is subjected to the forces of three members. Determine the tension force in member C and its angle θ for equilibrium. The forces are concurrent at point O. Take $F = 8$ kN.

$\xrightarrow{+} \Sigma F_x = 0; \quad T\cos\phi - 8\left(\frac{4}{5}\right) = 0 \quad (1)$

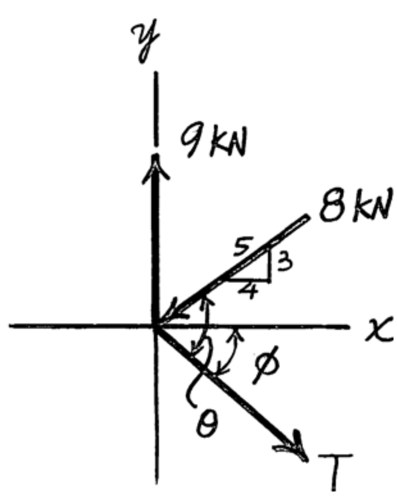
$+\uparrow \Sigma F_y = 0; \quad 9 - 8\left(\frac{3}{5}\right) - T\sin\phi = 0 \quad (2)$

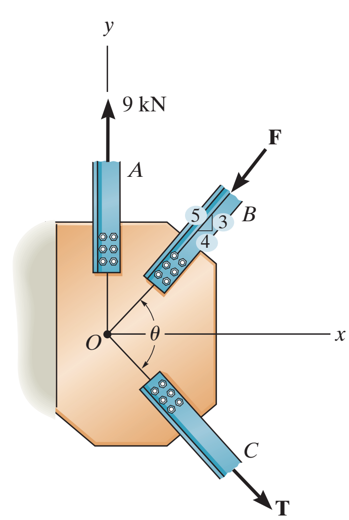
Rearrange then divide Eq. (1) into Eq. (2):

$\tan\phi = 0.656, \quad \phi = 33.27°$

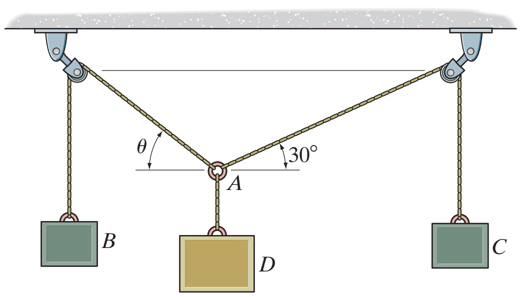
$T = 7.66 \text{ kN}$ **Ans**

$\theta = \phi + \tan^{-1}\left(\frac{3}{4}\right) = 70.1°$ **Ans**





***3–12.** If block *B* weighs 200 lb and block *C* weighs 100 lb, determine the required weight of block *D* and the angle θ for equilibrium.



Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free-body diagram shown in Fig. (a),

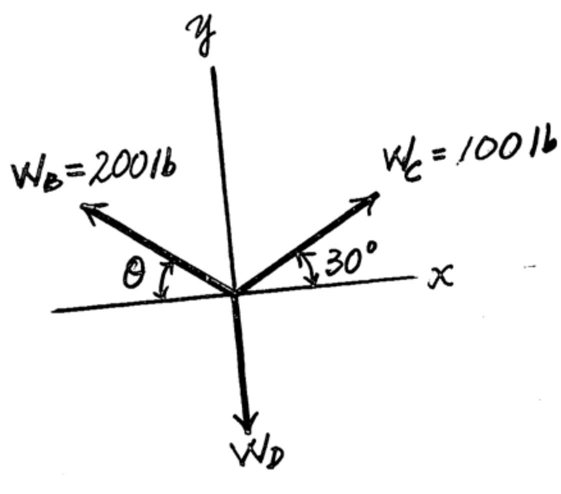
$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 100\cos 30° - 200\cos\theta = 0$

$\theta = 64.34° = 64.3°$ **Ans.**

Using this result and writing the equation of equilibrium along the y axis, yields

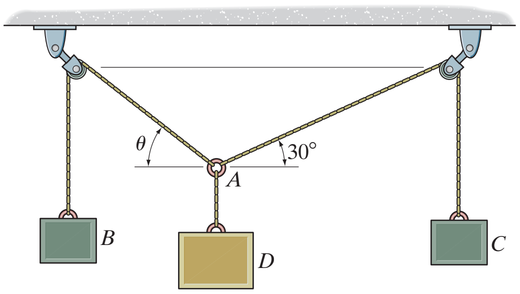
$+\uparrow \Sigma F_y = 0;$ $\quad 100\sin 30° + 200\sin 64.34° - W_D = 0$

$W_D = 230 \text{ lb}$ **Ans.**



(a)

•**3–13.** If block D weighs 300 lb and block B weighs 275 lb, determine the required weight of block C and the angle θ for equilibrium.



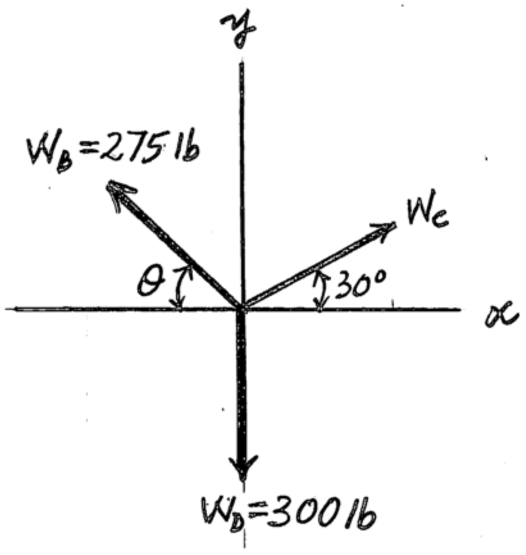
Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free-body diagram shown in Fig. (a),

$$\xrightarrow{+} \Sigma F_x = 0; \qquad W_C \cos 30° - 275 \cos\theta = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad W_C \sin 30° + 275 \sin\theta - 300 = 0 \qquad (2)$$

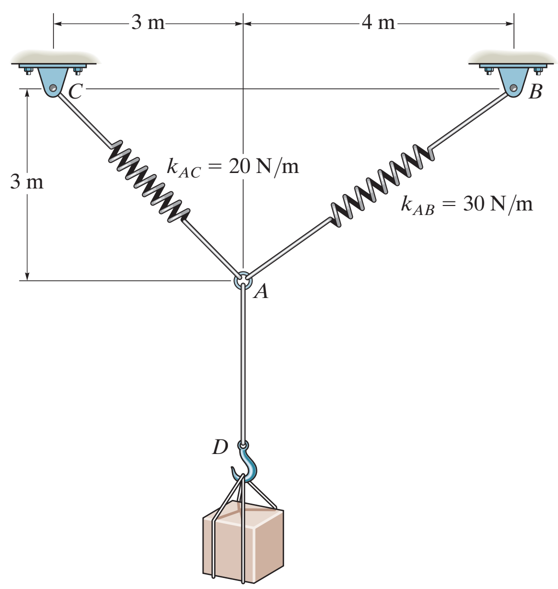
Solving Eqs. (1) and (2), yields

$$\theta = 40.9° \qquad W_C = 240 \text{ lb} \qquad \textbf{Ans.}$$



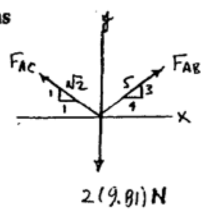
(a)

3–14. Determine the stretch in springs *AC* and *AB* for equilibrium of the 2-kg block. The springs are shown in the equilibrium position.



$F_{AD} = 2(9.81) = x_{AD}(40)$

$x_{AD} = 0.4905$ m **Ans**



$\xrightarrow{+} \Sigma F_x = 0; \quad F_{AB}\left(\frac{4}{5}\right) - F_{AC}\left(\frac{1}{\sqrt{2}}\right) = 0$

$+\uparrow \Sigma F_y = 0; \quad F_{AC}\left(\frac{1}{\sqrt{2}}\right) + F_{AB}\left(\frac{3}{5}\right) - 2(9.81) = 0$

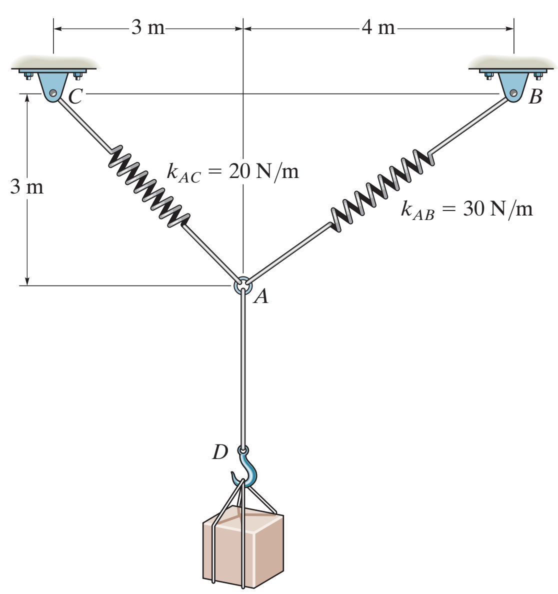
$F_{AC} = 15.86$ N

$x_{AC} = \frac{15.86}{20} = 0.793$ m **Ans**

$F_{AB} = 14.01$ N

$x_{AB} = \frac{14.01}{30} = 0.467$ m **Ans**

3–15. The unstretched length of spring *AB* is 3 m. If the block is held in the equilibrium position shown, determine the mass of the block at *D*.



$F = kx = 30(5 - 3) = 60$ N

$\xrightarrow{+} \Sigma F_x = 0; \quad T\cos 45° - 60\left(\frac{4}{5}\right) = 0$

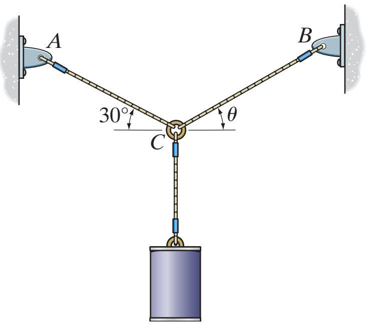
$T = 67.88$ N

$+\uparrow \Sigma F_y = 0; \quad -W + 67.88 \sin 45° + 60\left(\frac{3}{5}\right) = 0$

$W = 84$ N

$m = \frac{84}{9.81} = 8.56$ kg **Ans.**

***3–16.** Determine the tension developed in wires *CA* and *CB* required for equilibrium of the 10-kg cylinder. Take $\theta = 40°$.



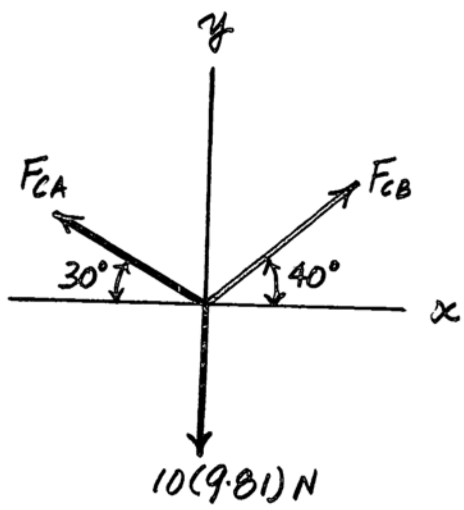
Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free-body diagram shown in Fig. (a),

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{CB}\cos 40° - F_{CA}\cos 30° = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{CB}\sin 40° + F_{CA}\sin 30° - 10(9.81) = 0 \qquad (2)$$

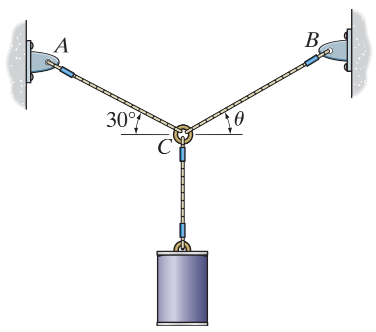
Solving Eqs. (1) and (2), yields

$F_{CA} = 80.0\text{ N}$ $\qquad F_{CB} = 90.4\text{ N}$ **Ans.**



(a)

•**3–17.** If cable CB is subjected to a tension that is twice that of cable CA, determine the angle θ for equilibrium of the 10-kg cylinder. Also, what are the tensions in wires CA and CB?



Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes,

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{CB} \cos\theta - F_{CA} \cos 30° = 0$ (1)

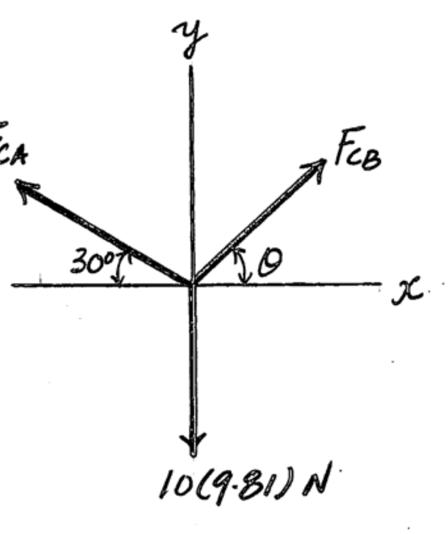
$+\uparrow \Sigma F_y = 0;$ $\quad F_{CB} \sin\theta + F_{CA} \sin 30° - 10(9.81) = 0$ (2)

However, it is required that

$F_{CB} = 2F_{CA}$ (3)

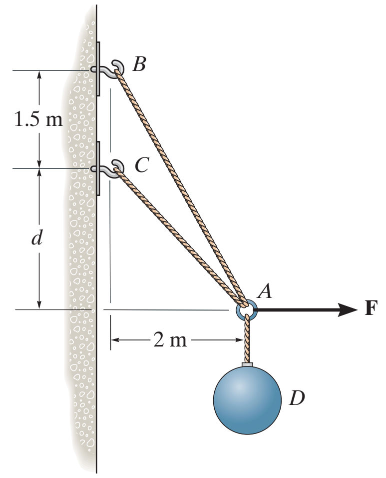
Solving Eqs. (1) and (2), yields

$\theta = 64.3°$ $\quad F_{CB} = 85.2\text{ N}$ $\quad F_{CA} = 42.6\text{ N}$ **Ans.**



(a)

3–18. Determine the forces in cables AC and AB needed to hold the 20-kg ball D in equilibrium. Take $F = 300$ N and $d = 1$ m.



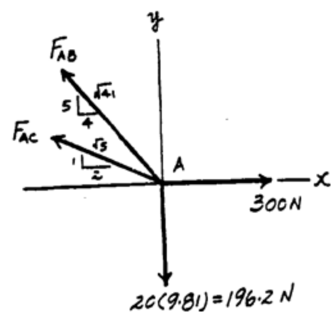
Equations of Equilibrium :

$$\xrightarrow{+} \Sigma F_x = 0; \quad 300 - F_{AB}\left(\frac{4}{\sqrt{41}}\right) - F_{AC}\left(\frac{2}{\sqrt{5}}\right) = 0$$

$$0.6247F_{AB} + 0.8944F_{AC} = 300 \qquad [1]$$

$$+\uparrow \Sigma F_y = 0; \quad F_{AB}\left(\frac{5}{\sqrt{41}}\right) + F_{AC}\left(\frac{1}{\sqrt{5}}\right) - 196.2 = 0$$

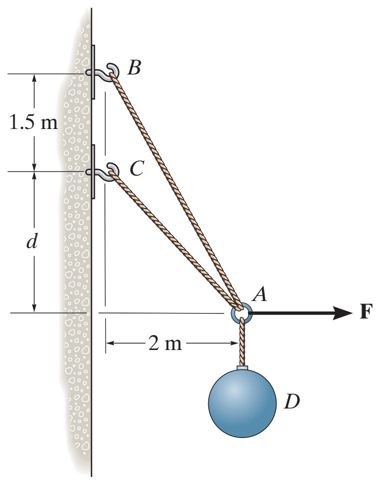
$$0.7809F_{AB} + 0.4472F_{AC} = 196.2 \qquad [2]$$



Solving Eqs. [1] and [2] yields

$$F_{AB} = 98.6 \text{ N} \qquad F_{AC} = 267 \text{ N} \qquad \textbf{Ans}$$

3–19. The ball D has a mass of 20 kg. If a force of $F = 100$ N is applied horizontally to the ring at A, determine the dimension d so that the force in cable AC is zero.



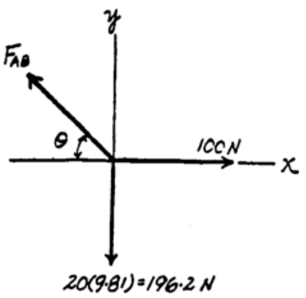
Equations of Equilibrium :

$$\xrightarrow{+} \Sigma F_x = 0; \quad 100 - F_{AB}\cos\theta = 0 \quad F_{AB}\cos\theta = 100 \quad [1]$$

$$+\uparrow \Sigma F_y = 0; \quad F_{AB}\sin\theta - 196.2 = 0 \quad F_{AB}\sin\theta = 196.2 \quad [2]$$

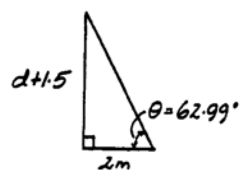
Solving Eqs. [1] and [2] yields

$$\theta = 62.99° \quad F_{AB} = 220.21 \text{ N}$$

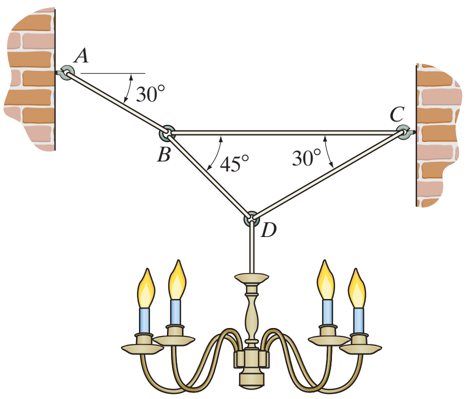


From the geometry,

$$d + 1.5 = 2\tan 62.99°$$
$$d = 2.42 \text{ m} \quad \textbf{Ans}$$



***3–20.** Determine the tension developed in each wire used to support the 50-kg chandelier.



Equations of Equilibrium: First, we will apply the equations of equilibrium along the *x* and *y* axes to the free-body diagram of joint *D* shown in Fig. (*a*).

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{CD}\cos 30° - F_{BD}\cos 45° = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{CD}\sin 30° + F_{BD}\sin 45° - 50(9.81) = 0 \qquad (2)$$

Solving Eqs. (1) and (2), yields

$$F_{CD} = 359\text{ N} \qquad F_{BD} = 439.77\text{ N} = 440\text{ N} \qquad \textbf{Ans.}$$

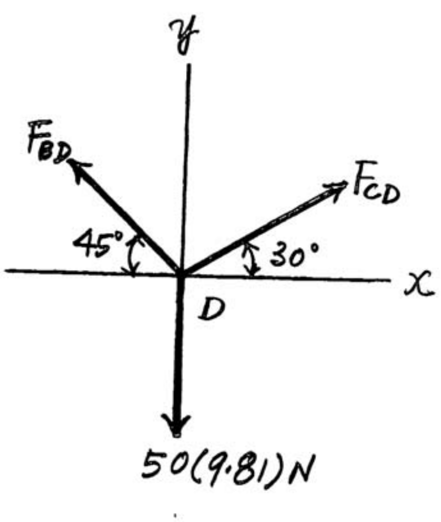
Using the result $F_{BD} = 439.77$ N and applying the equations of equilibrium along the *x* and *y* axes to the free-body diagram of joint *B* shown in Fig. (*b*),

$$+\uparrow \Sigma F_y = 0; \qquad F_{AB}\sin 30° - 439.77\sin 45° = 0$$

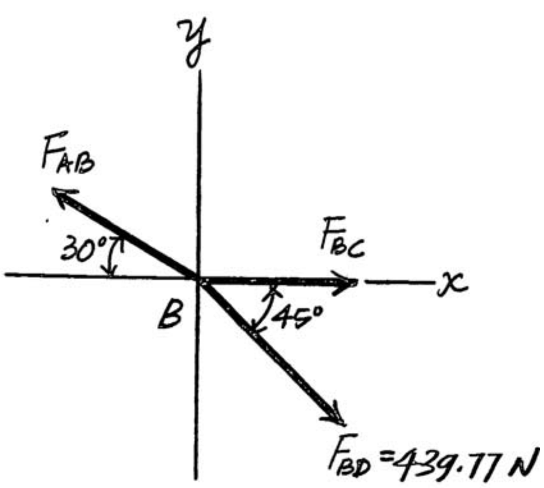
$$F_{AB} = 621.93\text{ N} = 622\text{ N} \qquad \textbf{Ans.}$$

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{BC} + 439.77\cos 45° - 621.93\cos 30° = 0$$

$$F_{BC} = 228\text{ N} \qquad \textbf{Ans.}$$

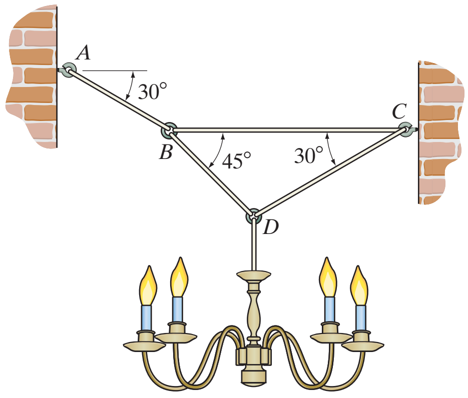


(a)



(b)

•3–21. If the tension developed in each of the four wires is not allowed to exceed 600 N, determine the maximum mass of the chandelier that can be supported.



Equations of Equilibrium: First, we will apply the equation of equilibrium along the *x* and *y* axes to the free-body diagram of joint *D* shown in Fig. (*a*).

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{CD} \cos 30° - F_{BD} \cos 45° = 0 \quad (1)$

$+\uparrow \Sigma F_y = 0;$ $\quad F_{CD} \sin 30° + F_{BD} \sin 45° - m(9.81) = 0 \quad (2)$

Solving Eqs. (1) and (2), yields

$F_{CD} = 7.1814m \qquad F_{BD} = 8.7954m$

Using the result $F_{BD} = 8.7954m$ and applying the equation of equilibrium along the *x* and *y* axes to the free-body diagram of joint *B* shown in Fig. (*b*),

$+\uparrow \Sigma F_y = 0;$ $\quad F_{AB} \sin 30° - 8.7954m \sin 45° = 0$

$F_{AB} = 12.4386m$

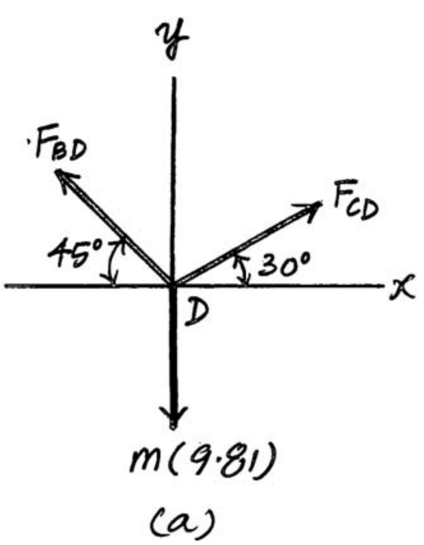
$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{BC} + 8.7954m \cos 45° - 12.4386m \cos 30° = 0$

$F_{BC} = 4.5528m$

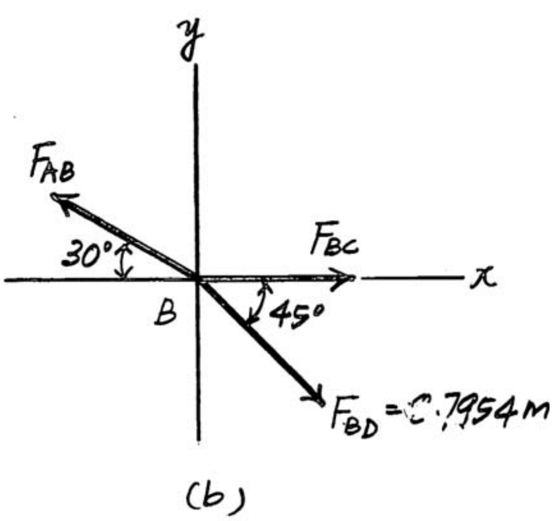
From this result, notice that cable *AB* is subjected to the greatest tensile force. Thus, it will achieve the maximum allowable tensile force first.

$F_{AB} = 600 = 12.4386m$

$m = 48.2 \text{ kg}$ **Ans.**

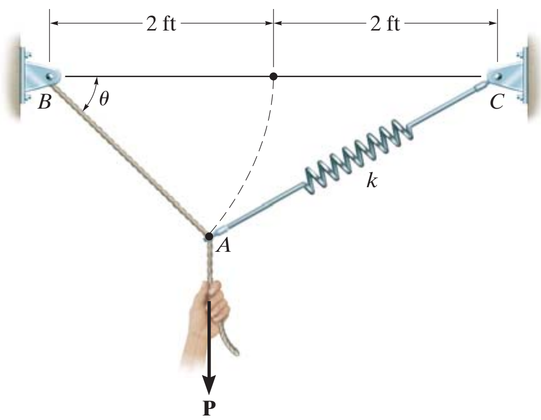


(a)



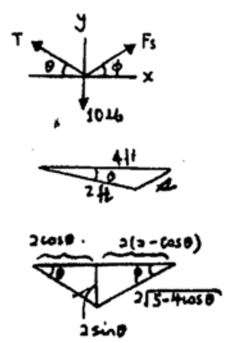
(b)

■**3–22.** A vertical force $P = 10$ lb is applied to the ends of the 2-ft cord AB and spring AC. If the spring has an unstretched length of 2 ft, determine the angle θ for equilibrium. Take $k = 15$ lb/ft.



$\xrightarrow{+}\Sigma F_x = 0; \qquad F_s \cos\phi - T\cos\theta = 0 \qquad (1)$

$+\uparrow \Sigma F_y = 0; \qquad T\sin\theta + F_s \sin\phi - 10 = 0 \qquad (2)$



$$s = \sqrt{(4)^2 + (2)^2 - 2(4)(2)\cos\theta} - 2 = 2\sqrt{5 - 4\cos\theta} - 2$$

$$F_s = ks = 2k(\sqrt{5-4\cos\theta} - 1)$$

From Eq. (1): $\quad T = F_s\left(\dfrac{\cos\phi}{\cos\theta}\right)$

$$T = 2k(\sqrt{5-4\cos\theta} - 1)\left(\frac{2-\cos\theta}{\sqrt{5-4\cos\theta}}\right)\left(\frac{1}{\cos\theta}\right)$$

From Eq. (2):

$$\frac{2k\left(\sqrt{5-4\cos\theta} - 1\right)(2-\cos\theta)}{\sqrt{5-4\cos\theta}}\tan\theta + \frac{2k\left(\sqrt{5-4\cos\theta} - 1\right)2\sin\theta}{2\sqrt{5-4\cos\theta}} = 10$$

$$\frac{\left(\sqrt{5-4\cos\theta} - 1\right)}{\sqrt{5-4\cos\theta}}(2\tan\theta - \sin\theta + \sin\theta) = \frac{10}{2k}$$

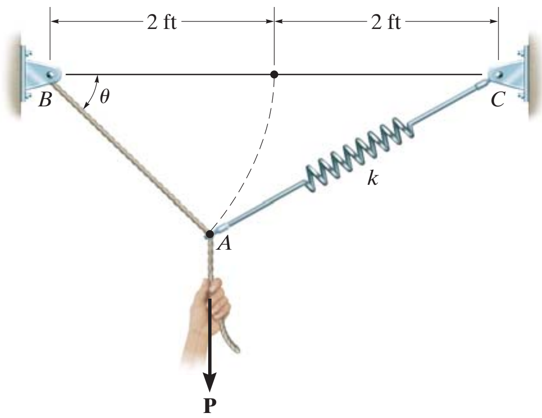
$$\frac{\tan\theta\left(\sqrt{5-4\cos\theta} - 1\right)}{\sqrt{5-4\cos\theta}} = \frac{10}{4k}$$

Set $k = 15$ lb/ft

Solving for θ by trial and error,

$\theta = 35.0°$ **Ans**

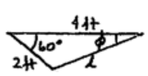
3–23. Determine the unstretched length of spring AC if a force $P = 80$ lb causes the angle $\theta = 60°$ for equilibrium. Cord AB is 2 ft long. Take $k = 50$ lb/ft.



$$l = \sqrt{4^2 + 2^2 - 2(2)(4)\cos 60°}$$

$$l = \sqrt{12}$$

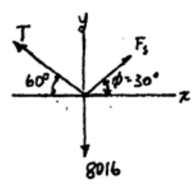
$$\frac{\sqrt{12}}{\sin 60°} = \frac{2}{\sin\phi}$$



$$\phi = \sin^{-1}\left(\frac{2\sin 60°}{\sqrt{12}}\right) = 30°$$

$+\uparrow \Sigma F_y = 0; \qquad T\sin 60° + F_s \sin 30° - 80 = 0$

$\xrightarrow{+} \Sigma F_x = 0; \qquad -T\cos 60° + F_s \cos 30° = 0$



Solving for F_s,

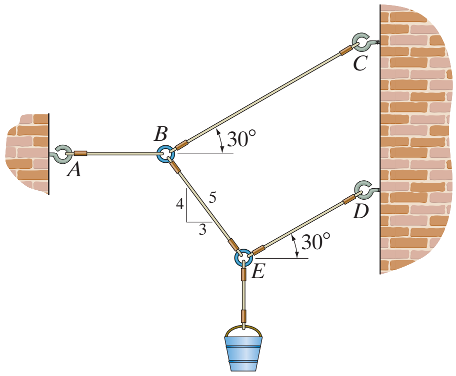
$F_s = 40$ lb

$F_s = kx$

$40 = 50(\sqrt{12} - l')$

$$l = \sqrt{12} - \frac{40}{50} = 2.66\text{ft} \qquad \textbf{Ans.}$$

***3–24.** If the bucket weighs 50 lb, determine the tension developed in each of the wires.



Equations of Equilibrium: First, we will apply the equation of equilibrium along the *x* and *y* axes to the free-body diagram of joint *E* shown in Fig. (*a*).

$\overset{+}{\rightarrow}\Sigma F_x = 0;\qquad F_{ED}\cos 30° - F_{EB}\left(\frac{3}{5}\right) = 0 \qquad (1)$

$+\uparrow \Sigma F_y = 0;\qquad F_{ED}\sin 30° + F_{EB}\left(\frac{4}{5}\right) - 50 = 0 \qquad (2)$

Solving Eqs. (1) and (2), yields

$F_{ED} = 30.2\text{ lb} \qquad F_{EB} = 43.61\text{ lb} = 43.6\text{ lb}$ **Ans.**

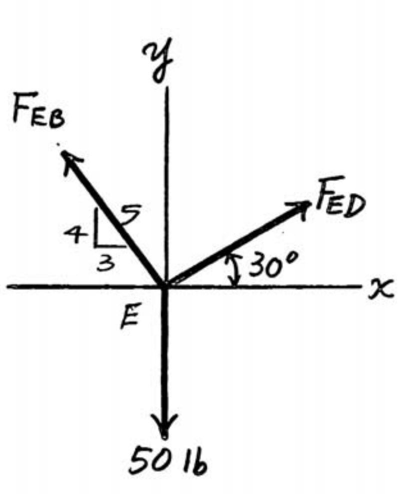
Using the result $F_{EB} = 43.61$ lb and applying the equation of equilibrium to the free-body diagram of joint *B* shown in Fig. (*b*),

$+\uparrow \Sigma F_y = 0;\qquad F_{BC}\sin 30° - 43.61\left(\frac{4}{5}\right) = 0$

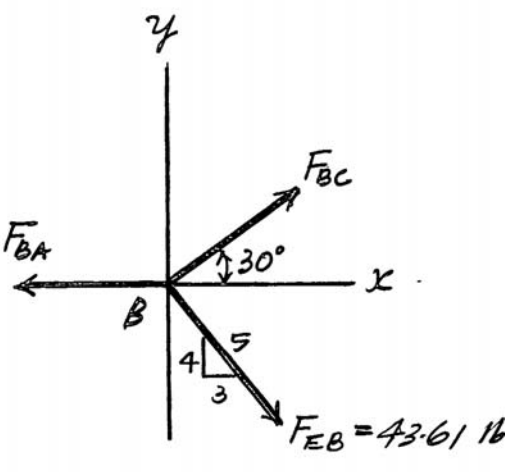
$F_{BC} = 69.78\text{ lb} = 69.8\text{ lb}$ **Ans.**

$\overset{+}{\rightarrow}\Sigma F_x = 0;\qquad 69.78\cos 30° + 43.61\left(\frac{3}{5}\right) - F_{BA} = 0$

$F_{BA} = 86.6\text{ lb}$ **Ans.**

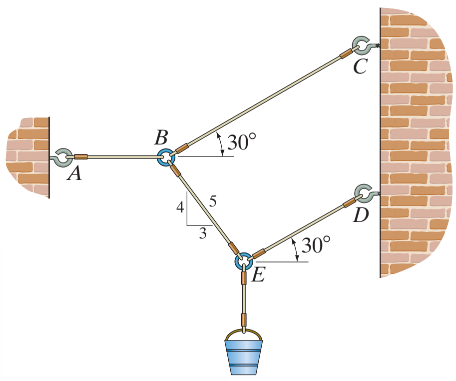


(a)



(b)

•3–25. Determine the maximum weight of the bucket that the wire system can support so that no single wire develops a tension exceeding 100 lb.



Equations of Equilibrium: First, we will apply the equations of equilibrium along the x and y axes to the free-body diagram of joint E shown in Fig. (a).

$$\xrightarrow{+}\Sigma F_x = 0; \qquad F_{ED}\cos 30° - F_{EB}\left(\frac{3}{5}\right) = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{ED}\sin 30° + F_{EB}\left(\frac{4}{5}\right) - W = 0 \qquad (2)$$

Solving,

$$F_{EB} = 0.8723W \qquad F_{ED} = 0.6043W$$

Using the result $F_{EB} = 0.8723W$ and applying the equations of equilibrium to the free-body diagram of joint B shown in Fig. (b),

$$+\uparrow \Sigma F_y = 0; \qquad F_{BC}\sin 30° - 0.8723W\left(\frac{4}{5}\right) = 0$$

$$F_{BC} = 1.3957W$$

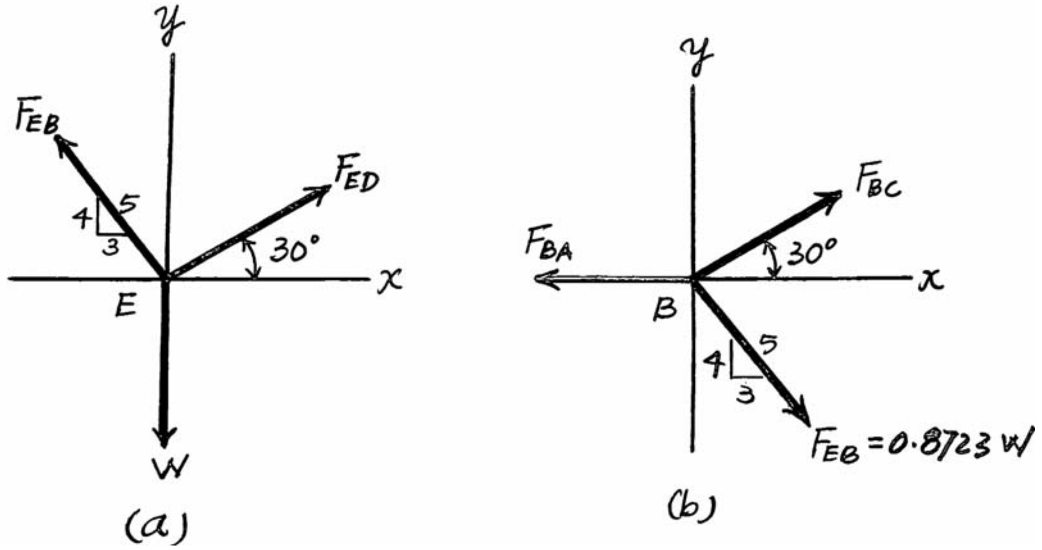
$$\xrightarrow{+}\Sigma F_x = 0; \qquad 1.3957W\cos 30° + 0.8723W\left(\frac{3}{5}\right) - F_{BA} = 0$$

$$F_{BA} = 1.7320W$$

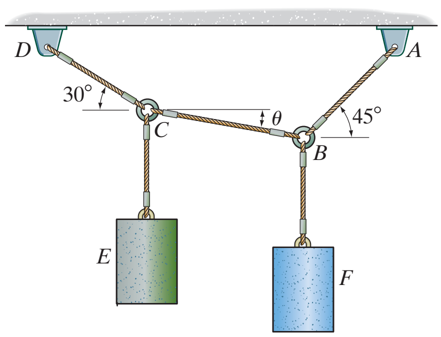
From these results, notice that wire BA is subjected to the greatest tensile force. Thus, it will achieve the maximum allowable tensile force first.

$$F_{BA} = 100 = 1.7320W$$

$$W = 57.7 \text{ lb} \qquad \textbf{Ans.}$$



3–26. Determine the tensions developed in wires CD, CB, and BA and the angle θ required for equilibrium of the 30-lb cylinder E and the 60-lb cylinder F.



Equations of Equilibrium: Applying the equations of equilibrium along the x and y axes to the free-body diagram of joint C shown in Fig. (a),

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{BC} \cos\theta - F_{CD} \cos 30° = 0 \quad (1)$

$+\uparrow \Sigma F_y = 0;$ $\quad -F_{BC} \sin\theta + F_{CD} \sin 30° - 30 = 0 \quad (2)$

By referring to the free-body diagram of joint B in Fig. (b),

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{BA} \cos 45° - F_{BC} \cos\theta = 0 \quad (3)$

$+\uparrow \Sigma F_y = 0;$ $\quad F_{BA} \sin 45° + F_{BC} \sin\theta - 60 = 0 \quad (4)$

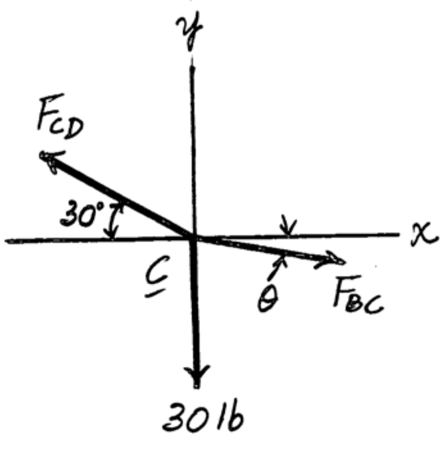
Solving Eqs. (1) through (4), yields

$F_{BA} = 80.7 \text{ lb}$ **Ans.**

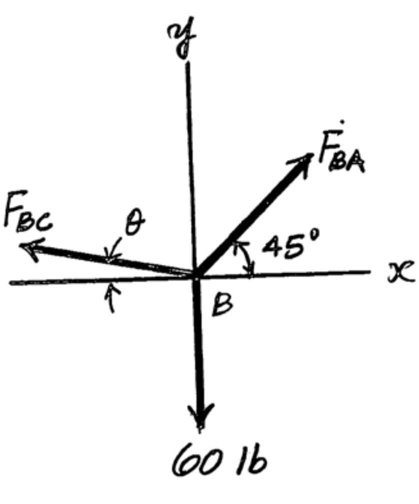
$F_{CD} = 65.9 \text{ lb}$ **Ans.**

$F_{BC} = 57.1 \text{ lb}$ **Ans.**

$\theta = 2.95°$ **Ans.**

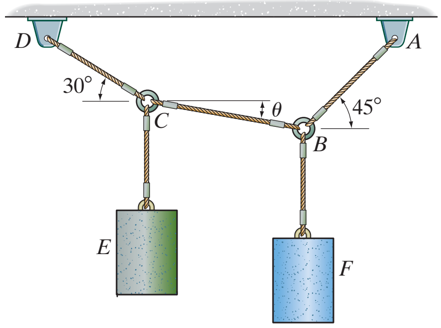


(a)



(b)

3–27. If cylinder E weighs 30 lb and $\theta = 15°$, determine the weight of cylinder F.



Equations of Equilibrium: First, we will apply the equation of equilibrium along the x and y axes to the free-body diagram of joint C shown in Fig. (a).

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{BC}\cos 15° - F_{CD}\cos 30° = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{CD}\sin 30° - F_{BC}\sin 15° - 30 = 0 \qquad (2)$$

Solving Eqs. (1) and (2), yields

$F_{BC} = 100.38$ lb $\qquad F_{CD} = 111.96$ lb $\qquad$ **Ans.**

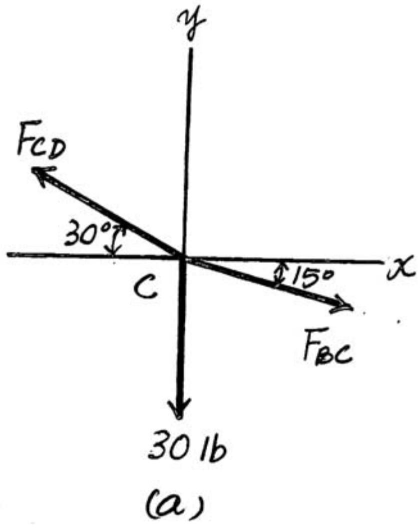
Using the result $F_{BC} = 100.38$ lb and applying the equation of equilibrium along the x and y axes to the free-body diagram of joint B shown in Fig. (b),

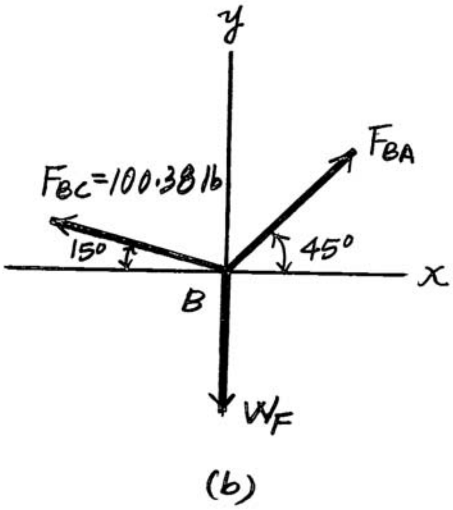
$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{BA}\cos 45° - 100.38\cos 15° = 0$$

$F_{BA} = 137.12$ lb $\qquad$ **Ans.**

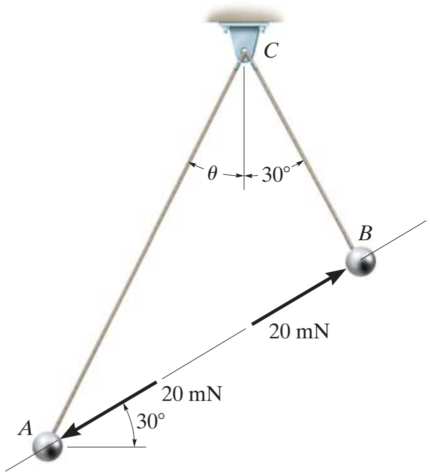
$$+\uparrow \Sigma F_y = 0; \qquad 137.12\sin 45° + 100.38\sin 15° - W_F = 0$$

$W_F = 123$ lb $\qquad$ **Ans.**





***3–28.** Two spheres A and B have an equal mass and are electrostatically charged such that the repulsive force acting between them has a magnitude of 20 mN and is directed along line AB. Determine the angle θ, the tension in cords AC and BC, and the mass m of each sphere.



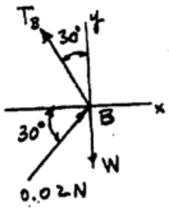
For B:

$\xrightarrow{+} \Sigma F_x = 0; \quad 0.02 \cos 30° - T_B \sin 30° = 0$

$+\uparrow \Sigma F_y = 0; \quad 0.02 \sin 30° + T_B \cos 30° - W = 0$

$T_B = 0.0346 \text{ N} = 34.6 \text{ mN}$ **Ans**

$W = 0.04 \text{ N}$



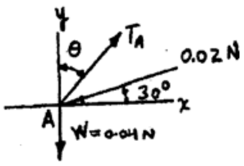
For A:

$\xrightarrow{+} \Sigma F_x = 0; \quad T_A \sin\theta - 0.02 \cos 30° = 0$

$+\uparrow \Sigma F_y = 0; \quad T_A \cos\theta - 0.02 \sin 30° - 0.04 = 0$

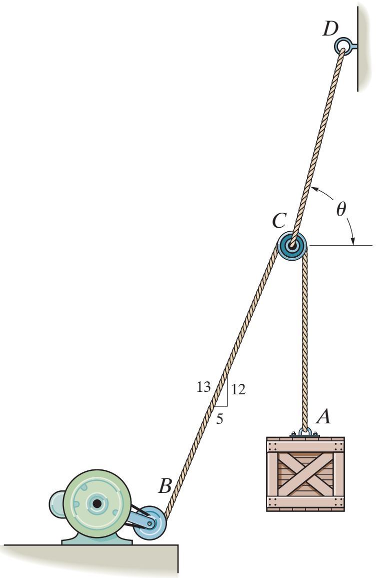
$T_A = 0.0529 \text{ N} = 52.9 \text{ mN}$ **Ans**

$\theta = 19.1°$ **Ans**



$$m = \frac{W}{g} = \frac{0.04}{9.81} = 4.08\,(10^{-3}) \text{ kg} = 4.08 \text{ g}$$ **Ans**

•3–29. The cords BCA and CD can each support a maximum load of 100 lb. Determine the maximum weight of the crate that can be hoisted at constant velocity and the angle θ for equilibrium. Neglect the size of the smooth pulley at C.

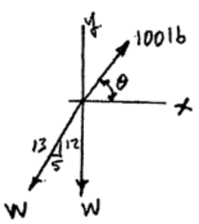


$\xrightarrow{+} \Sigma F_x = 0; \quad 100 \cos\theta = W\left(\frac{5}{13}\right)$

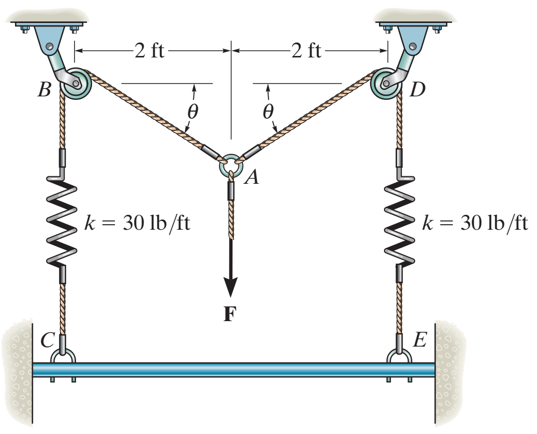
$+\uparrow \Sigma F_y = 0; \quad 100 \sin\theta = W\left(\frac{12}{13}\right) + W$

$\theta = 78.7°$ **Ans**

$W = 51.0 \text{ lb}$ **Ans**

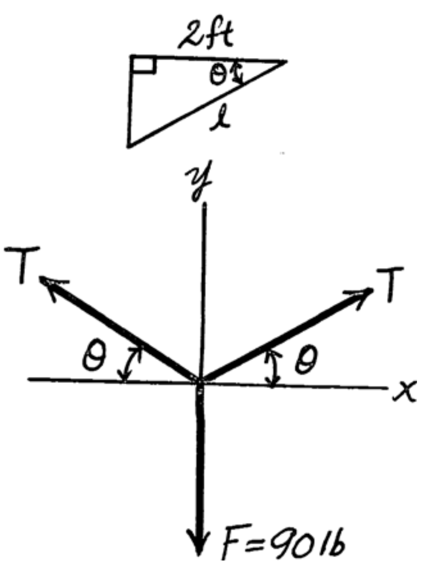


3–30. The springs on the rope assembly are originally unstretched when $\theta = 0°$. Determine the tension in each rope when $F = 90$ lb. Neglect the size of the pulleys at B and D.



$$l = \frac{2}{\cos\theta}$$

$$T = kx = k(l - l_0) = 30\left(\frac{2}{\cos\theta} - 2\right) = 60\left(\frac{1}{\cos\theta} - 1\right) \qquad (1)$$



$+\uparrow \Sigma F_y = 0; \qquad 2T\sin\theta - 90 = 0 \qquad (2)$

Substituting Eq. (1) into (2) yields :

$$120(\tan\theta - \sin\theta) - 90 = 0$$

$$\tan\theta - \sin\theta = 0.75$$

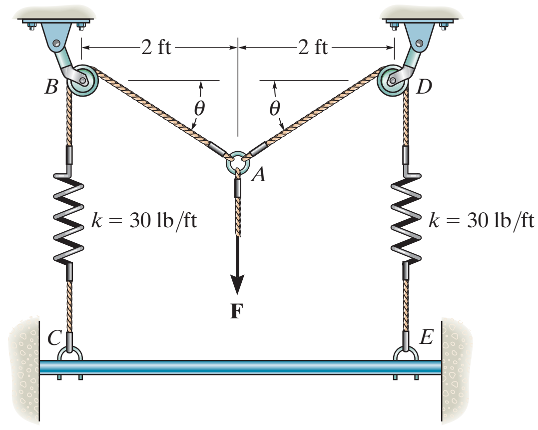
By trial and error :

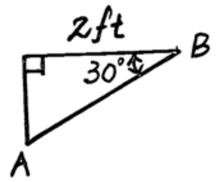
$$\theta = 57.957°$$

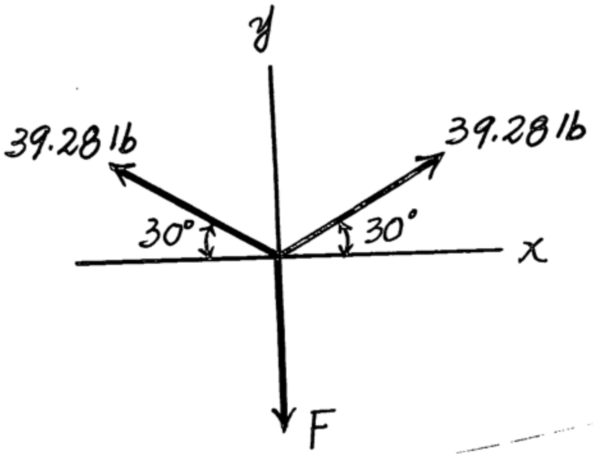
From Eq. (1),

$$T = 60\left(\frac{1}{\cos 57.957°} - 1\right) = 53.1 \text{ lb} \qquad \textbf{Ans}$$

3–31. The springs on the rope assembly are originally stretched 1 ft when $\theta = 0°$. Determine the vertical force F that must be applied so that $\theta = 30°$.







$$BA = \frac{2}{\cos 30°} = 2.3094 \text{ ft}$$

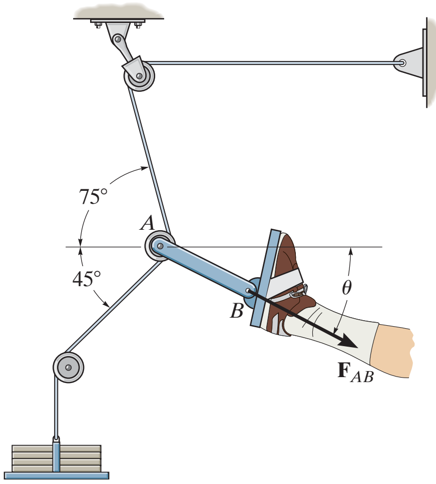
When $\theta = 30°$, the springs are stretched 1 ft + (2.3094 − 2) ft = 1.3094 ft

$F_s = kx = 30(1.3094) = 39.28$ lb

$+\uparrow \Sigma F_y = 0; \quad 2(39.28) \sin 30° - F = 0$

$F = 39.3$ lb **Ans**

***3–32.** Determine the magnitude and direction θ of the equilibrium force F_{AB} exerted along link AB by the tractive apparatus shown. The suspended mass is 10 kg. Neglect the size of the pulley at A.



Free Body Diagram : The tension in the cord is the same throughout the cord, that is $10(9.81) = 9.81$ N.

Equations of Equilibrium :

$\xrightarrow{+} \Sigma F_x = 0;\quad F_{AB}\cos\theta - 98.1\cos 75° - 98.1\cos 45° = 0$

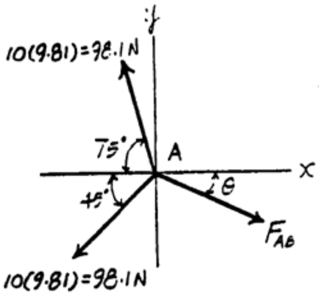
$F_{AB}\cos\theta = 94.757 \qquad [1]$

$+\uparrow \Sigma F_y = 0;\quad 98.1\sin 75° - 98.1\sin 45° - F_{AB}\sin\theta = 0$

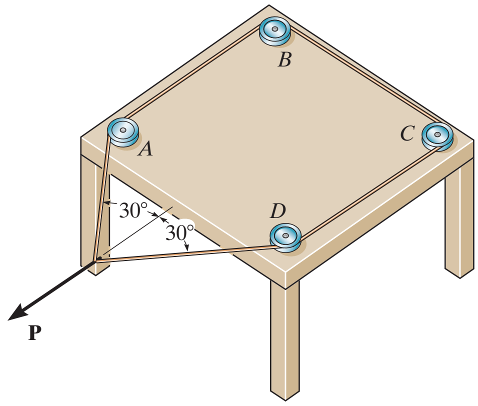
$F_{AB}\sin\theta = 25.390 \qquad [2]$

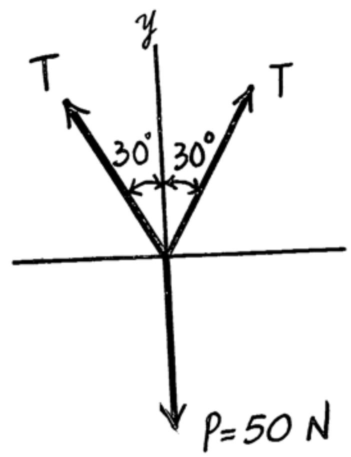
Solving Eqs. [1] and [2] yields

$\theta = 15.0° \qquad F_{AB} = 98.1\text{ N} \qquad$ **Ans**



•3–33. The wire forms a loop and passes over the small pulleys at A, B, C, and D. If its end is subjected to a force of $P = 50$ N, determine the force in the wire and the magnitude of the resultant force that the wire exerts on each of the pulleys.





$+\uparrow \Sigma F_y = 0;\quad 2(T\cos 30°) - 50 = 0$

$T = 28.868 = 28.9\text{ N}$ **Ans**

For A and D:

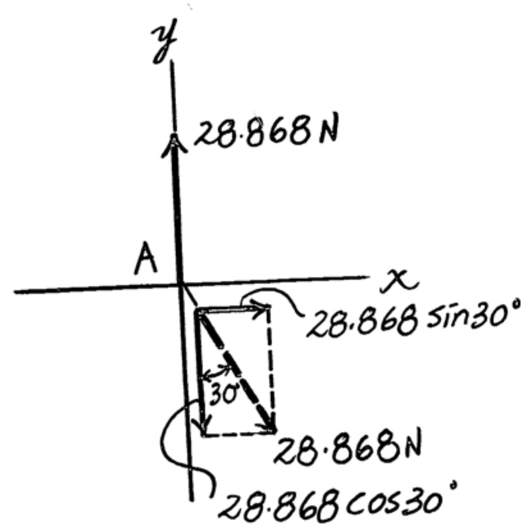
$F_{Rx} = \Sigma F_x;\quad F_{Rx} = 28.868 \sin 30° = 14.43\text{ N}$

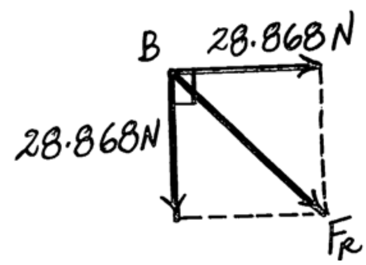
$F_{Rx} = \Sigma F_y;\quad F_{Ry} = 28.868 - 28.868\cos 30° = 3.868\text{ N}$

$F_R = \sqrt{(14.43)^2 + (3.868)^2} = 14.9\text{ N}$ (A and D) **Ans**

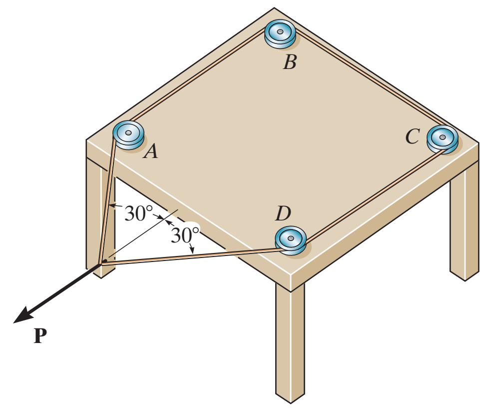
For B and C:

$F_R = \sqrt{(28.868)^2 + (28.868)^2} = 40.8\text{ N}$ (B and C) **Ans**





3–34. The wire forms a loop and passes over the small pulleys at A, B, C, and D. If the maximum *resultant force* that the wire can exert on each pulley is 120 N, determine the greatest force P that can be applied to the wire as shown.



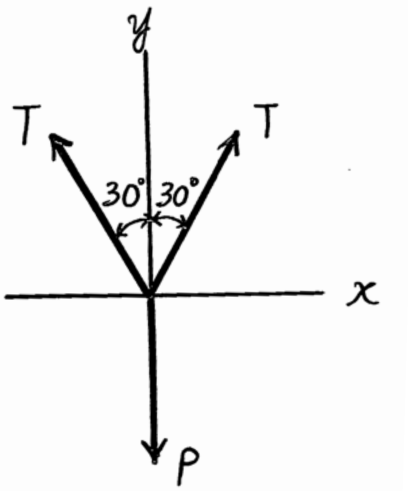
$+\uparrow \Sigma F_y = 0; \quad 2T\cos 30° - P = 0; \quad T = 0.57735P$

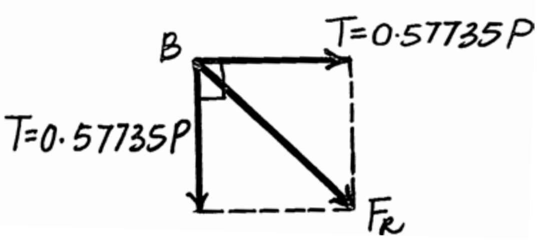
Maximum resultant force is resisted by pulleys B and C.

$$F_R = \sqrt{(0.57735P)^2 + (0.57735P)^2}$$

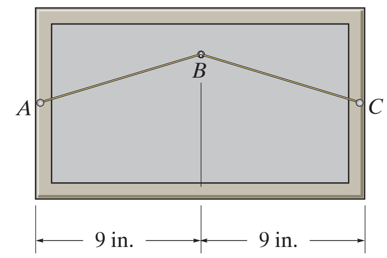
$$F_R = 0.8165P = 120$$

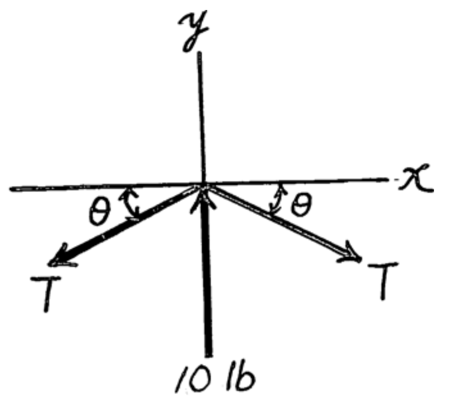
$$P = 147 \text{ N} \qquad \textbf{Ans}$$





3–35. The picture has a weight of 10 lb and is to be hung over the smooth pin B. If a string is attached to the frame at points A and C, and the maximum force the string can support is 15 lb, determine the shortest string that can be safely used.





Free Body Diagram : Since the pin is smooth, the tension force in the cord is the same throughout the cord.

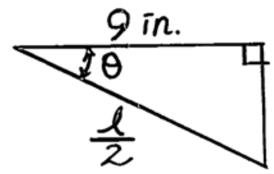
Equations of Equilibrium :

$\xrightarrow{+} \Sigma F_x = 0;\quad T\cos\theta - T\cos\theta = 0 \quad$ ***(Satisfied!)***

$+\uparrow \Sigma F_y = 0;\quad 10 - 2T\sin\theta = 0 \quad T = \dfrac{5}{\sin\theta}$

If tension in the cord cannot exceed 15 lb, then

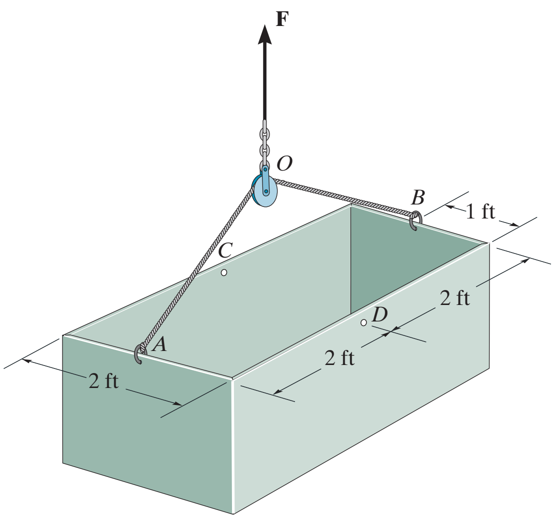
$$\frac{5}{\sin\theta} = 15$$
$$\theta = 19.47^\circ$$



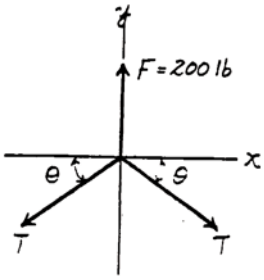
From the geometry, $\dfrac{l}{2} = \dfrac{9}{\cos\theta}$ and $\theta = 19.47^\circ$. Therefore

$$l = \frac{18}{\cos 19.47^\circ} = 19.1 \text{ in.} \qquad \textbf{Ans}$$

***3–36.** The 200-lb uniform tank is suspended by means of a 6-ft-long cable, which is attached to the sides of the tank and passes over the small pulley located at *O*. If the cable can be attached at either points *A* and *B* or *C* and *D*, determine which attachment produces the least amount of tension in the cable. What is this tension?



Free Body Diagram : By observation, the force **F** has to support the entire weight of the tank. Thus, $F = 200$ lb. The tension in cable is the same throughout the cable.

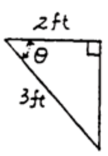


Equations of Equilibrium :

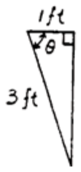
$$\xrightarrow{+} \Sigma F_x = 0; \quad T\cos\theta - T\cos\theta = 0 \quad (\textit{Satisfied!})$$

$$+\uparrow \Sigma F_y = 0; \quad 200 - 2T\sin\theta = 0 \quad T = \frac{100}{\sin\theta} \qquad [1]$$

From the function obtained above, one realizes that in order to produce the least amount of tension in the cable, $\sin\theta$ hence θ must be as great as possible. Since the attachment of the cable to point *C* and *D* produces a greater θ $\left(\theta = \cos^{-1}\frac{1}{3} = 70.53°\right)$ as compared to the attachment of the cable to points *A* and *B* $\left(\theta = \cos^{-1}\frac{2}{3} = 48.19°\right)$,



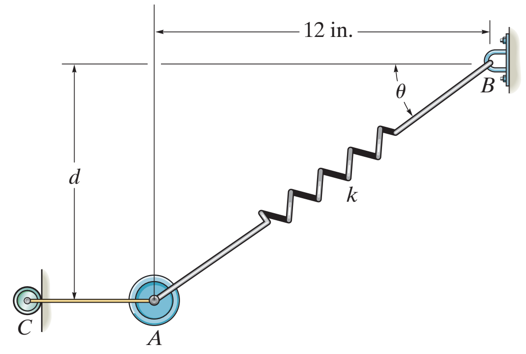
The attachment of the cable to point *C* and *D* will produce the least amount of tension in the cable. **Ans**

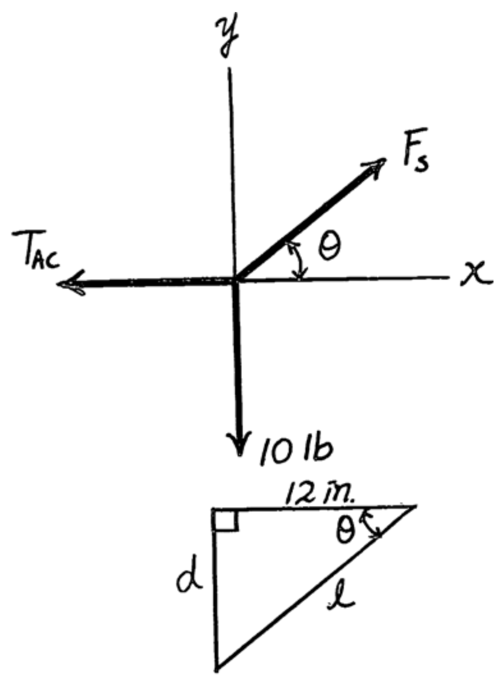


Thus,

$$T = \frac{100}{\sin 70.53°} = 106 \text{ lb} \qquad \textbf{Ans}$$

•■**3–37.** The 10-lb weight is supported by the cord *AC* and roller and by the spring that has a stiffness of $k = 10$ lb/in. and an unstretched length of 12 in. Determine the distance d to where the weight is located when it is in equilibrium.





$\xrightarrow{+} \Sigma F_x = 0; \quad -T_{AC} + F_s \cos\theta = 0$

$+\uparrow \Sigma F_y = 0; \quad F_s \sin\theta - 10 = 0$

$F_s = kx; \quad F_s = 10\left(\frac{12}{\cos\theta} - 12\right)$

$= 120(\sec\theta - 1)$

Thus,

$$120(\sec\theta - 1)\sin\theta = 10$$

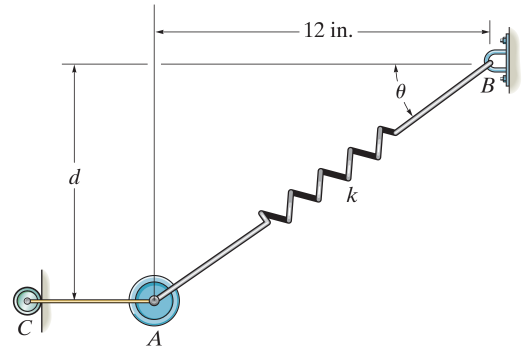
$$(\tan\theta - \sin\theta) = \frac{1}{12}$$

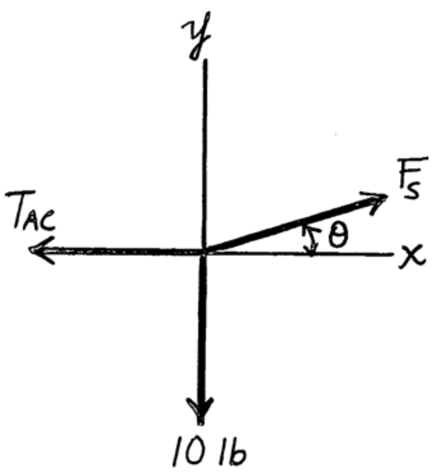
Solving,

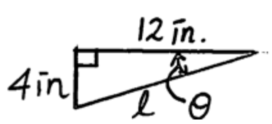
$$\theta = 30.71^\circ$$

$$d = 12\tan 30.71^\circ = 7.13 \text{ in.} \qquad \textbf{Ans}$$

3–38. The 10-lb weight is supported by the cord *AC* and roller and by a spring. If the spring has an unstretched length of 8 in. and the weight is in equilibrium when $d = 4$ in., determine the stiffness k of the spring.







$+\uparrow \Sigma F_y = 0; \quad F_s \sin\theta - 10 = 0$

$F_s = kx; \quad F_s = k\left(\frac{12}{\cos\theta} - 8\right)$

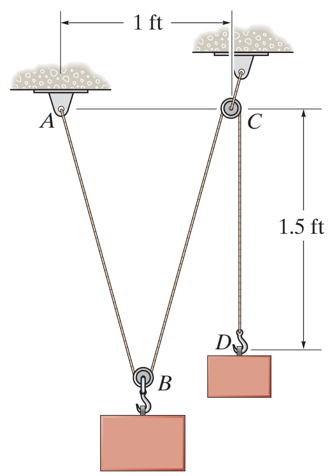
$\tan\theta = \frac{4}{12}; \quad \theta = 18.435°$

Thus,

$k\left(\frac{12}{\cos 18.435°} - 8\right)\sin 18.435° = 10$

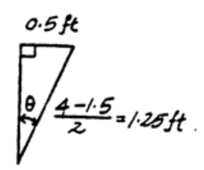
$k = 6.80$ lb/in. **Ans**

•3–39. A "scale" is constructed with a 4-ft-long cord and the 10-lb block D. The cord is fixed to a pin at A and passes over two *small* pulleys at B and C. Determine the weight of the suspended block at B if the system is in equilibrium.



Free Body Diagram : The tension force in the cord is the same throughout the cord, that is 10 lb. From the geometry,

$\theta = \sin^{-1}\left(\frac{0.5}{1.25}\right) = 23.58°$.

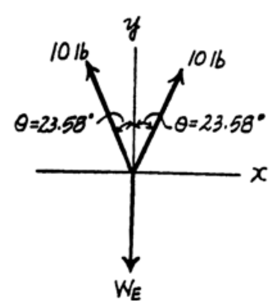


Equations of Equilibrium :

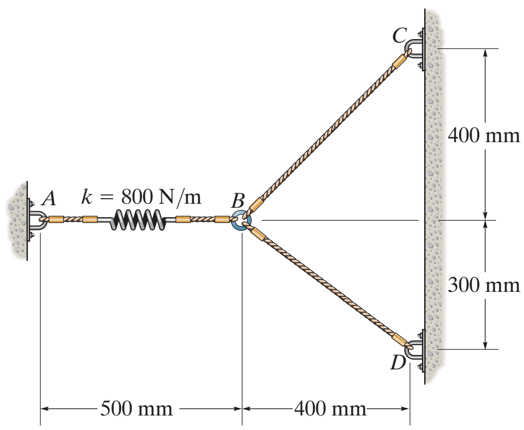
$\xrightarrow{+} \Sigma F_x = 0;\quad 10\sin 23.58° - 10\sin 23.58° = 0 \quad$ ***(Satisfied!)***

$+\uparrow \Sigma F_y = 0;\quad 2(10)\cos 23.58° - W_E = 0$

$W_E = 18.3 \text{ lb}$ **Ans**



•*3–40. The spring has a stiffness of $k = 800$ N/m and an unstretched length of 200 mm. Determine the force in cables BC and BD when the spring is held in the position shown.



The Force in The Spring : The spring stretches $s = l - l_0 = 0.5 - 0.2 = 0.3$ m. Applying Eq. 3–2, we have

$$F_{sp} = ks = 800(0.3) = 240 \text{ N}$$

Equations of Equilibrium :

$\xrightarrow{+} \Sigma F_x = 0;\quad F_{BC}\cos 45° + F_{BD}\left(\frac{4}{5}\right) - 240 = 0$

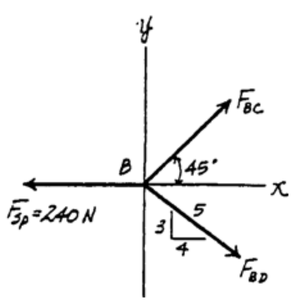
$0.7071F_{BC} + 0.8F_{BD} = 240 \quad$ **[1]**

$+\uparrow \Sigma F_y = 0;\quad F_{BC}\sin 45° - F_{BD}\left(\frac{3}{5}\right) = 0$

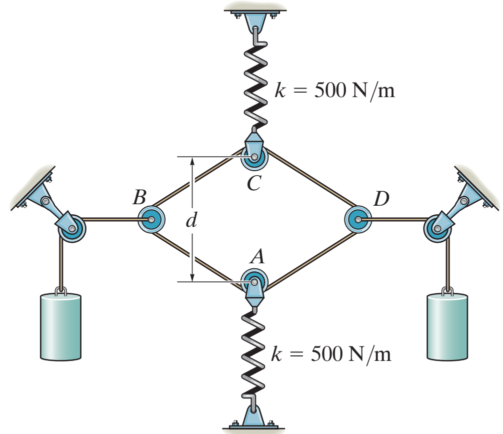
$F_{BC} = 0.8485F_{BD} \quad$ **[2]**

Solving Eqs. [1] and [2] yields,

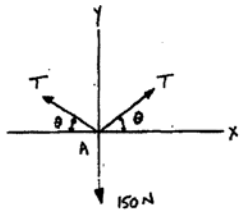
$F_{BD} = 171 \text{ N} \quad F_{BC} = 145 \text{ N}$ **Ans**



•3–41. A continuous cable of total length 4 m is wrapped around the *small* pulleys at *A*, *B*, *C*, and *D*. If each spring is stretched 300 mm, determine the mass *m* of each block. Neglect the weight of the pulleys and cords. The springs are unstretched when $d = 2$ m.



$F_s = kx;\quad F_s = 500(0.3) = 150\text{ N}$

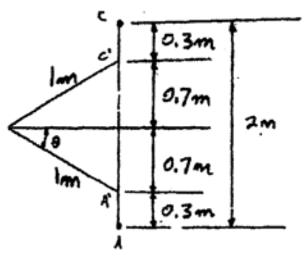


At *A*:

$+\uparrow \Sigma F_y = 0;\quad -150 + 2T\sin\theta = 0$

$$T = \frac{75}{\sin\theta} \quad (1)$$

Note that when $\theta = 90°$, the springs are unstretched and the tension in the cord is zero. When the springs are stretched 300 mm = 0.3 m, then $d = (2 - 2(0.3)) = 1.4$ m



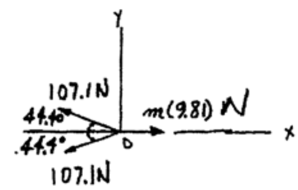
$$\theta = \sin^{-1}\left(\frac{0.7}{1}\right) = 44.4°$$

From Eq. (1), $T = 107.1$ N

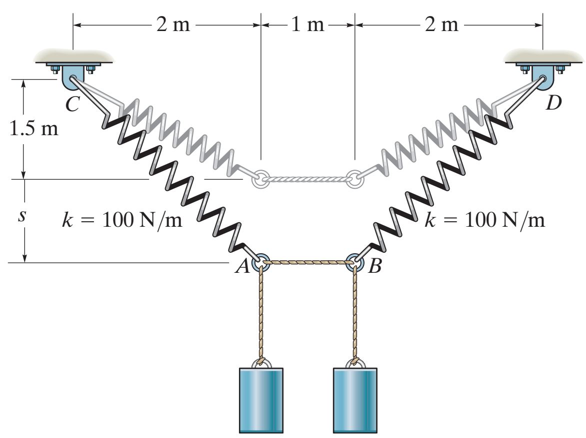
At *D*:

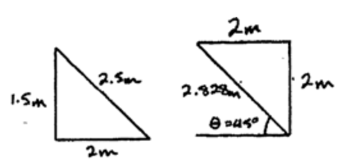
$\xrightarrow{+} \Sigma F_x = 0;\quad -2(107.1)\cos 44.4° + m(9.81) = 0$

$m = 15.6$ kg **Ans**



3–42. Determine the mass of each of the two cylinders if they cause a sag of $s = 0.5$ m when suspended from the rings at *A* and *B*. Note that $s = 0$ when the cylinders are removed.

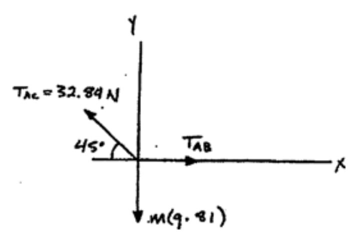




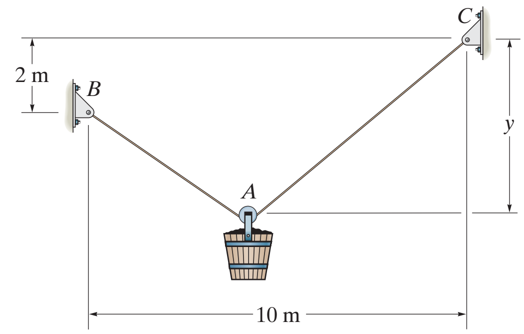
$T_{AC} = 100\text{ N/m}(2.828 - 2.5) = 32.84\text{ N}$

$+\uparrow \Sigma F_y = 0;\quad 32.84\sin 45° - m(9.81) = 0$

$m = 2.37$ kg **Ans**



•3–43. The pail and its contents have a mass of 60 kg. If the cable *BAC* is 15 m long, determine the distance *y* to the pulley at *A* for equilibrium. Neglect the size of the pulley.



Free Body Diagram : Since the pulley is smooth, the tension in the cable is the same throughout the cable.

Equations of Equilibrium :

$$\xrightarrow{+} \Sigma F_x = 0; \quad T\sin\theta - T\sin\phi = 0 \quad \theta = \phi$$

Geometry :

$$l_1 = \sqrt{(10-x)^2 + (y-2)^2} \qquad l_2 = \sqrt{x^2 + y^2}$$

Since $\theta = \phi$, two triangles are similar.

$$\frac{10-x}{x} = \frac{y-2}{y} = \frac{\sqrt{(10-x)^2 + (y-2)^2}}{\sqrt{x^2+y^2}} \qquad [1]$$

Also,

$$l_1 + l_2 = 15$$

$$\sqrt{(10-x)^2 + (y-2)^2} + \sqrt{x^2+y^2} = 15$$

$$\left(\frac{\sqrt{x^2+y^2}}{\sqrt{x^2+y^2}}\right)\sqrt{(10-x)^2 + (y-2)^2} + \sqrt{x^2+y^2} = 15 \qquad [2]$$

However, from Eq. [1] $\dfrac{\sqrt{(10-x)^2 + (y-2)^2}}{\sqrt{x^2+y^2}} = \dfrac{10-x}{x}$, Eq. [2] becomes

$$\sqrt{x^2+y^2}\left(\frac{10-x}{x}\right) + \sqrt{x^2+y^2} = 15 \qquad [3]$$

Dividing both sides of Eq. [3] by $\sqrt{x^2+y^2}$ yields

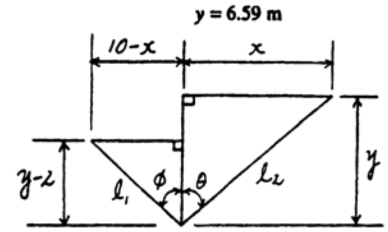
$$\frac{10}{x} = \frac{15}{\sqrt{x^2+y^2}} \qquad x = \sqrt{0.8}\,y \qquad [4]$$

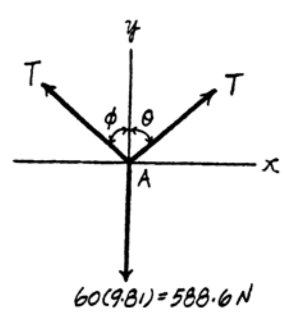
From Eq. [1] $\quad \dfrac{10-x}{x} = \dfrac{y-2}{y} \qquad x = \dfrac{5y}{y-1} \qquad [5]$

Equating Eq. [4] and [5] yields

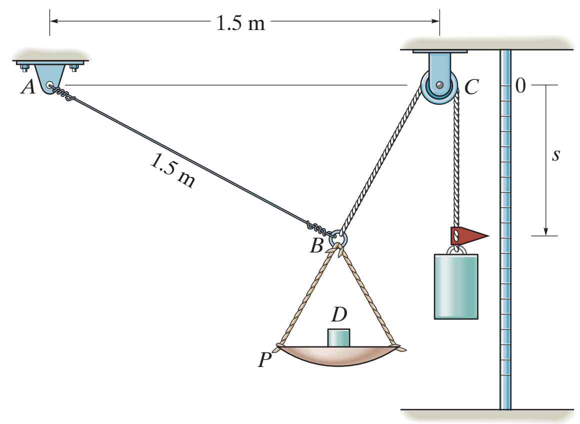
$$\sqrt{0.8}\,y = \frac{5y}{y-1}$$

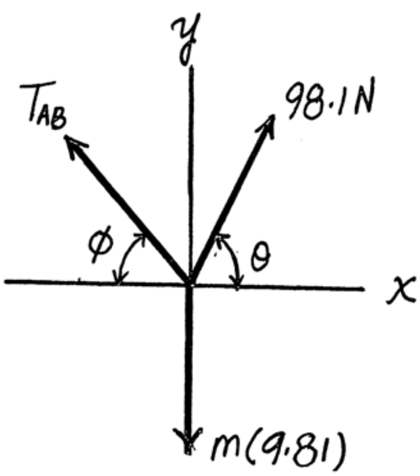
$$y = 6.59 \text{ m} \qquad \textbf{Ans}$$

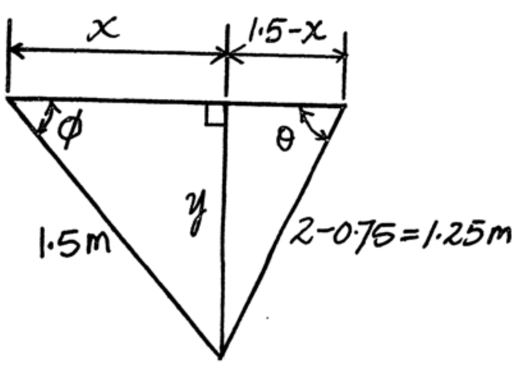




•*3–44. A scale is constructed using the 10-kg mass, the 2-kg pan P, and the pulley and cord arrangement. Cord BCA is 2 m long. If $s = 0.75$ m, determine the mass D in the pan. Neglect the size of the pulley.







$\xrightarrow{+} \Sigma F_x = 0;\quad 98.1\cos\theta - T_{AB}\cos\phi = 0 \quad (1)$

$+\uparrow \Sigma F_y = 0;\quad T_{AB}\sin\phi + 98.1\sin\theta - m(9.81) = 0 \quad (2)$

$$(1.5)^2 = x^2 + y^2$$

$$(1.25)^2 = (1.5 - x)^2 + y^2$$

$$(1.25)^2 = (1.5 - x)^2 + (1.5)^2 - x^2$$

$$-3x + 2.9375 = 0$$

$$x = 0.9792 \text{ m}$$

$$y = 1.1363 \text{ m}$$

Thus,

$$\phi = \sin^{-1}\left(\frac{1.1363}{1.5}\right) = 49.25°$$

$$\theta = \sin^{-1}\left(\frac{1.1363}{1.25}\right) = 65.38°$$

Solving Eq. (1) and (2),

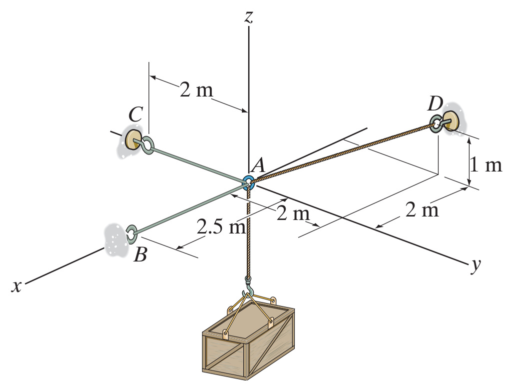
$$T_{AB} = 62.62 \text{ N}$$

$$m = 13.9 \text{ kg}$$

Therefore,

$$m_D = 13.9 \text{ kg} - 2 \text{ kg} = 11.9 \text{ kg} \quad \textbf{Ans}$$

•3–45. Determine the tension in the cables in order to support the 100-kg crate in the equilibrium position shown.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{i}$$
$$\mathbf{F}_{AC} = -F_{AC}\,\mathbf{j}$$
$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(-2-0)\mathbf{i}+(2-0)\mathbf{j}+(1-0)\mathbf{k}}{\sqrt{(-2-0)^2+(2-0)^2+(1-0)^2}}\right] = -\frac{2}{3}F_{AD}\mathbf{i}+\frac{2}{3}F_{AD}\mathbf{j}+\frac{1}{3}F_{AD}\mathbf{k}$$
$$\mathbf{W} = [-100(9.81)\mathbf{k}]\text{ N} = [-981\,\mathbf{k}]\text{ N}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{W} = \mathbf{0}$$
$$F_{AB}\,\mathbf{i}+(-F_{AC}\,\mathbf{j})+\left(-\frac{2}{3}F_{AD}\mathbf{i}+\frac{2}{3}F_{AD}\mathbf{j}+\frac{1}{3}F_{AD}\mathbf{k}\right)+(-981\mathbf{k}) = \mathbf{0}$$
$$\left(F_{AB}-\frac{2}{3}F_{AD}\right)\mathbf{i}+\left(-F_{AC}+\frac{2}{3}F_{AD}\right)\mathbf{j}+\left(\frac{1}{3}F_{AD}-981\right)\mathbf{k} = \mathbf{0}$$

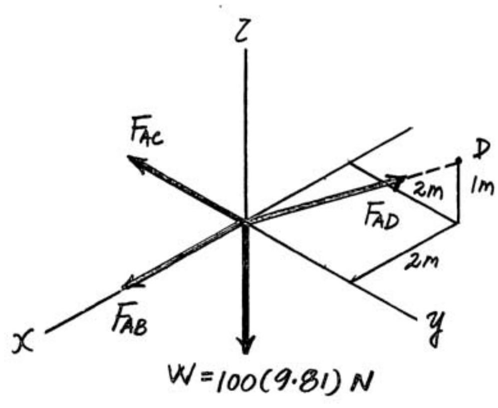
Equating the **i**, **j**, and **k** components yields

$$F_{AB}-\frac{2}{3}F_{AD} = 0 \qquad (1)$$
$$-F_{AC}+\frac{2}{3}F_{AD} = 0 \qquad (2)$$
$$\frac{1}{3}F_{AD}-981 = 0 \qquad (3)$$

Solving Eqs. (1) through (3) yields

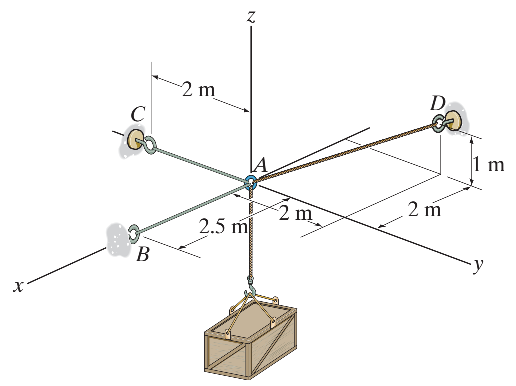
$F_{AD} = 2943\text{ N} = 2.94\text{ kN}$ **Ans.**

$F_{AB} = F_{AC} = 1962\text{ N} = 1.96\text{ kN}$ **Ans.**



(a)

3–46. Determine the maximum mass of the crate so that the tension developed in any cable does not exceeded 3 kN.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{i}$$

$$\mathbf{F}_{AC} = -F_{AC}\,\mathbf{j}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(-2-0)\mathbf{i}+(2-0)\mathbf{j}+(1-0)\mathbf{k}}{\sqrt{(-2-0)^2+(2-0)^2+(1-0)^2}}\right] = -\frac{2}{3}F_{AD}\mathbf{i}+\frac{2}{3}F_{AD}\mathbf{j}+\frac{1}{3}F_{AD}\mathbf{k}$$

$$\mathbf{W} = [-m(9.81)\mathbf{k}]$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \quad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = \mathbf{0}$$

$$F_{AB}\,\mathbf{i} + (-F_{AC}\,\mathbf{j}) + \left(-\frac{2}{3}F_{AD}\mathbf{i} + \frac{2}{3}F_{AD}\mathbf{j} + \frac{1}{3}F_{AD}\mathbf{k}\right) + [-m(9.81)\mathbf{k}] = \mathbf{0}$$

$$\left(F_{AB} - \frac{2}{3}F_{AD}\right)\mathbf{i} + \left(-F_{AC} + \frac{2}{3}F_{AD}\right)\mathbf{j} + \left(\frac{1}{3}F_{AD} - 9.81m\right)\mathbf{k} = 0$$

Equating the **i**, **j**, and **k** components yields

$$F_{AB} - \frac{2}{3}F_{AD} = 0 \qquad (1)$$

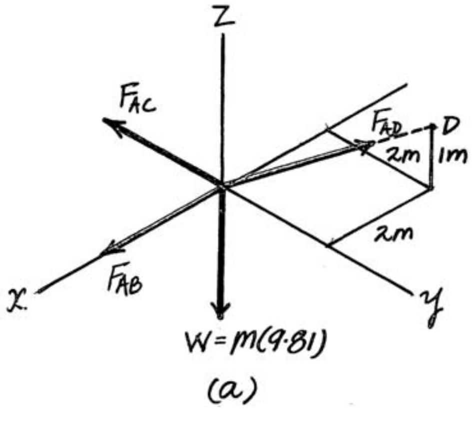
$$-F_{AC} + \frac{2}{3}F_{AD} = 0 \qquad (2)$$

$$\frac{1}{3}F_{AD} - 9.81m = 0 \qquad (3)$$

When cable *AD* is subjected to maximum tension, $F_{AD} = 3000$ N. Thus, by substituting this value into Eqs. (1) through (3), we have

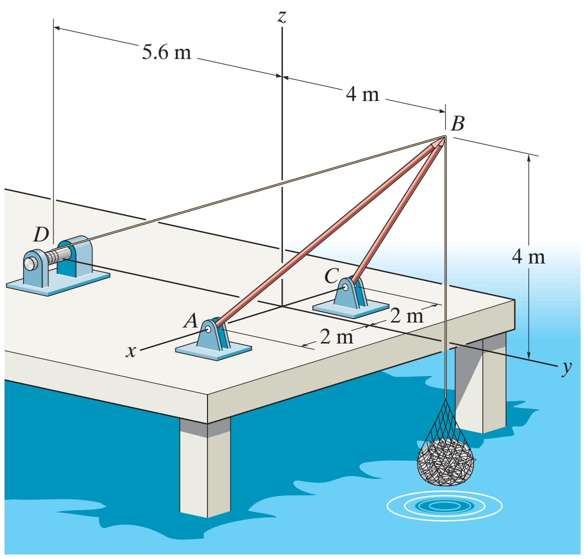
$$F_{AB} = F_{AC} = 2000\text{ N}$$

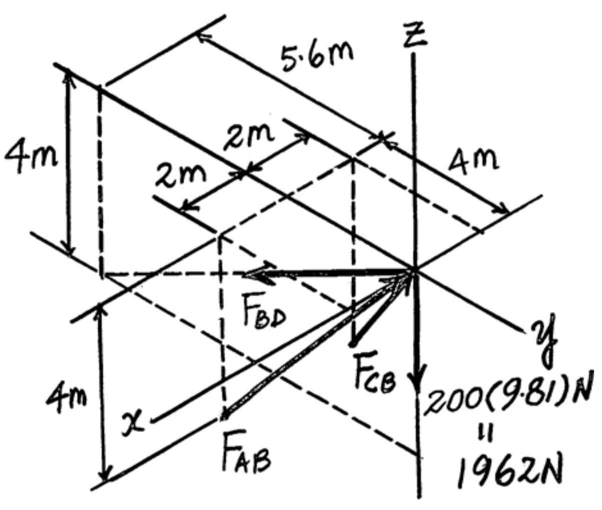
$$m = 102\text{ kg} \qquad \textbf{Ans.}$$



(a)

3–47. The shear leg derrick is used to haul the 200-kg net of fish onto the dock. Determine the compressive force along each of the legs *AB* and *CB* and the tension in the winch cable *DB*. Assume the force in each leg acts along its axis.





$$\mathbf{F}_{AB} = F_{AB}\left(-\frac{2}{6}\mathbf{i} + \frac{4}{6}\mathbf{j} + \frac{4}{6}\mathbf{k}\right)$$

$$= -0.3333\,F_{AB}\,\mathbf{i} + 0.6667\,F_{AB}\,\mathbf{j} + 0.6667\,F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{CB} = F_{CB}\left(\frac{2}{6}\mathbf{i} + \frac{4}{6}\mathbf{j} + \frac{4}{6}\mathbf{k}\right)$$

$$= 0.3333\,F_{CB}\,\mathbf{i} + 0.6667\,F_{CB}\,\mathbf{j} + 0.6667\,F_{CB}\,\mathbf{k}$$

$$\mathbf{F}_{BD} = F_{BD}\left(-\frac{9.6}{10.4}\mathbf{j} - \frac{4}{10.4}\mathbf{k}\right)$$

$$= -0.9231\,F_{BD}\,\mathbf{j} - 0.3846\,F_{BD}\,\mathbf{k}$$

$$\mathbf{W} = -1962\,\mathbf{k}$$

$\Sigma F_x = 0;\quad -0.3333\,F_{AB} + 0.3333\,F_{CB} = 0$

$\Sigma F_y = 0;\quad 0.6667\,F_{AB} + 0.6667\,F_{CB} - 0.9231\,F_{BD} = 0$

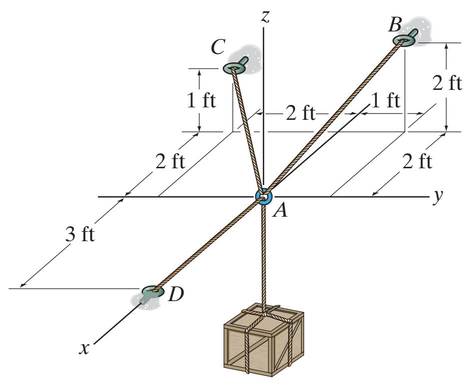
$\Sigma F_z = 0;\quad 0.6667\,F_{AB} + 0.6667\,F_{CB} - 0.3846\,F_{BD} - 1962 = 0$

$F_{AB} = 2.52$ kN **Ans**

$F_{CB} = 2.52$ kN **Ans**

$F_{BD} = 3.64$ kN **Ans**

***3–48.** Determine the tension developed in cables AB, AC, and AD required for equilibrium of the 300-lb crate.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (a) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-2-0)\mathbf{i}+(1-0)\mathbf{j}+(2-0)\mathbf{k}}{\sqrt{(-2-0)^2+(1-0)^2+(2-0)^2}}\right] = -\frac{2}{3}F_{AB}\mathbf{i}+\frac{1}{3}F_{AB}\mathbf{j}+\frac{2}{3}F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-2-0)\mathbf{i}+(-2-0)\mathbf{j}+(1-0)\mathbf{k}}{\sqrt{(-2-0)^2+(-2-0)^2+(1-0)^2}}\right] = -\frac{2}{3}F_{AC}\mathbf{i}-\frac{2}{3}F_{AC}\mathbf{j}+\frac{1}{3}F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\mathbf{i}$$

$$\mathbf{W} = [-300\mathbf{k}]\text{ lb}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{W} = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB}\mathbf{i}+\frac{1}{3}F_{AB}\mathbf{j}+\frac{2}{3}F_{AB}\mathbf{k}\right)+\left(-\frac{2}{3}F_{AC}\mathbf{i}-\frac{2}{3}F_{AC}\mathbf{j}+\frac{1}{3}F_{AC}\mathbf{k}\right)+F_{AD}\mathbf{i}+(-300\mathbf{k}) = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB}-\frac{2}{3}F_{AC}+F_{AD}\right)\mathbf{i}+\left(\frac{1}{3}F_{AB}-\frac{2}{3}F_{AC}\right)\mathbf{j}+\left(\frac{2}{3}F_{AB}+\frac{1}{3}F_{AC}-300\right)\mathbf{k} = \mathbf{0}$$

Equating the **i**, **j**, and **k** components yields

$$-\frac{2}{3}F_{AB}-\frac{2}{3}F_{AC}+F_{AD} = 0 \qquad (1)$$

$$\frac{1}{3}F_{AB}-\frac{2}{3}F_{AC} = 0 \qquad (2)$$

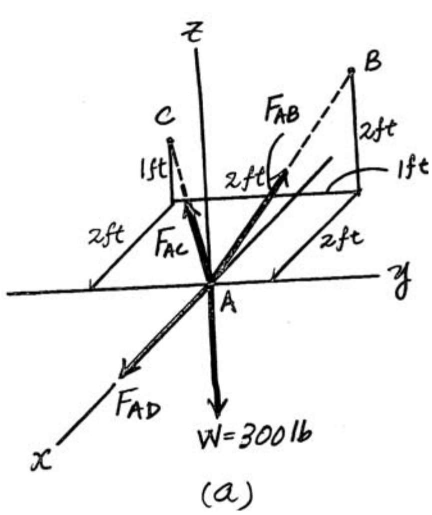
$$\frac{2}{3}F_{AB}+\frac{1}{3}F_{AC}-300 = 0 \qquad (3)$$

Solving Eqs. (1) through (3) yields

$F_{AB} = 360$ lb **Ans.**

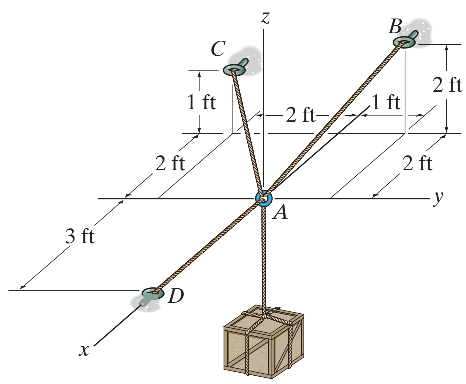
$F_{AC} = 180$ lb **Ans.**

$F_{AD} = 360$ lb **Ans.**



(a)

•3–49. Determine the maximum weight of the crate so that the tension developed in any cable does not exceed 450 lb.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-2-0)\mathbf{i}+(1-0)\mathbf{j}+(2-0)\mathbf{k}}{\sqrt{(-2-0)^2+(1-0)^2+(2-0)^2}}\right] = -\frac{2}{3}F_{AB}\mathbf{i}+\frac{1}{3}F_{AB}\mathbf{j}+\frac{2}{3}F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-2-0)\mathbf{i}+(-2-0)\mathbf{j}+(1-0)\mathbf{k}}{\sqrt{(-2-0)^2+(-2-0)^2+(1-0)^2}}\right] = -\frac{2}{3}F_{AC}\mathbf{i}-\frac{2}{3}F_{AC}\mathbf{j}+\frac{1}{3}F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\mathbf{i}$$

$$\mathbf{W} = -W\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{W} = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB}\mathbf{i}+\frac{1}{3}F_{AB}\mathbf{j}+\frac{2}{3}F_{AB}\mathbf{k}\right)+\left(-\frac{2}{3}F_{AC}\mathbf{i}-\frac{2}{3}F_{AC}\mathbf{j}+\frac{1}{3}F_{AC}\mathbf{k}\right)+F_{AD}\mathbf{i}+(-W\mathbf{k}) = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB}-\frac{2}{3}F_{AC}+F_{AD}\right)\mathbf{i}+\left(\frac{1}{3}F_{AB}-\frac{2}{3}F_{AC}\right)\mathbf{j}+\left(\frac{2}{3}F_{AB}+\frac{1}{3}F_{AC}-W\right)\mathbf{k} = \mathbf{0}$$

Equating the **i**, **j**, and **k** components yields

$$-\frac{2}{3}F_{AB}-\frac{2}{3}F_{AC}+F_{AD} = 0 \qquad (1)$$

$$\frac{1}{3}F_{AB}-\frac{2}{3}F_{AC} = 0 \qquad (2)$$

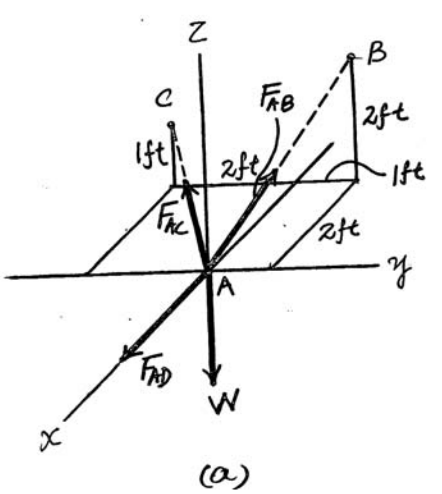
$$\frac{2}{3}F_{AB}+\frac{1}{3}F_{AC}-W = 0 \qquad (3)$$

Let us assume that cable *AB* achieves maximum tension first. Substituting $F_{AB} = 450$ lb into Eqs. (1) through (3) and solving, yields

$F_{AC} = 225$ lb $\qquad F_{AD} = 450$ lb

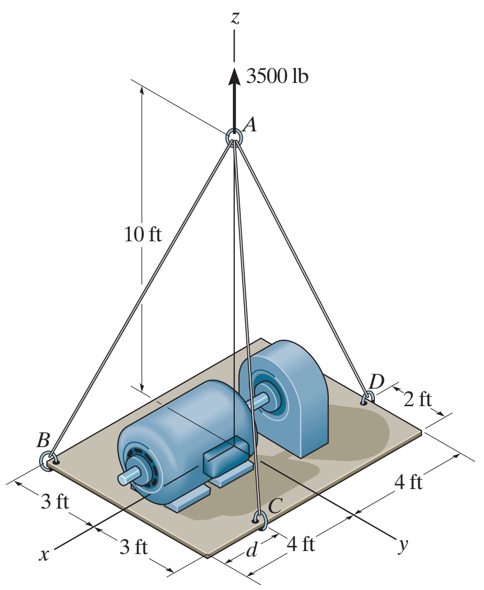
$W = 375$ lb $\qquad$ **Ans.**

Since $F_{AC} = 225\text{ lb} < 450\text{ lb}$, our assumption is correct.



(a)

3–50. Determine the force in each cable needed to support the 3500-lb platform. Set $d = 2$ ft.



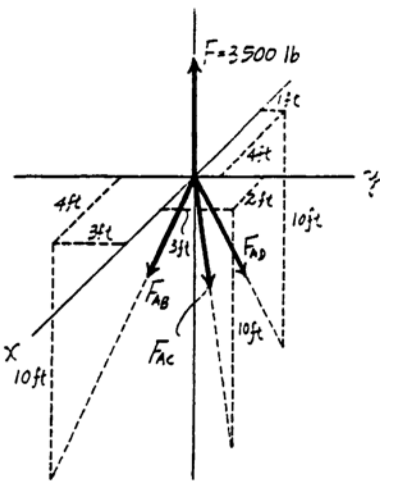
Cartesian Vector Notation :

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{4\mathbf{i} - 3\mathbf{j} - 10\mathbf{k}}{\sqrt{4^2 + (-3)^2 + (-10)^2}}\right) = 0.3578F_{AB}\mathbf{i} - 0.2683F_{AB}\mathbf{j} - 0.8944F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{2\mathbf{i} + 3\mathbf{j} - 10\mathbf{k}}{\sqrt{2^2 + 3^2 + (-10)^2}}\right) = 0.1881F_{AC}\mathbf{i} + 0.2822F_{AC}\mathbf{j} - 0.9407F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-4\mathbf{i} + 1\mathbf{j} - 10\mathbf{k}}{\sqrt{(-4)^2 + 1^2 + (-10)^2}}\right) = -0.3698F_{AD}\mathbf{i} + 0.09245F_{AD}\mathbf{j} - 0.9245F_{AD}\mathbf{k}$$

$$\mathbf{F} = \{3500\mathbf{k}\} \text{ lb}$$



Equations of Equilibrium :

$$\Sigma \mathbf{F} = 0; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{F} = \mathbf{0}$$

$$(0.3578F_{AB} + 0.1881F_{AC} - 0.3698F_{AD})\mathbf{i} + (-0.2683F_{AB} + 0.2822F_{AC} + 0.09245F_{AD})\mathbf{j}$$
$$+(-0.8944F_{AB} - 0.9407F_{AC} - 0.9245F_{AD} + 3500)\mathbf{k} = \mathbf{0}$$

Equating **i**, **j** and **k** components, we have

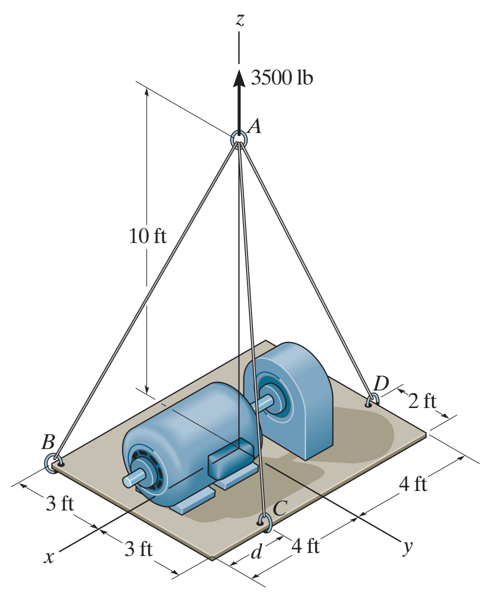
$$0.3578F_{AB} + 0.1881F_{AC} - 0.3698F_{AD} = 0 \qquad [1]$$
$$-0.2683F_{AB} + 0.2822F_{AC} + 0.09245F_{AD} = 0 \qquad [2]$$
$$-0.8944F_{AB} - 0.9407F_{AC} - 0.9245F_{AD} + 3500 = 0 \qquad [3]$$

Solving Eqs. [1], [2] and [3] yields

$F_{AB} = 1369.59$ lb $= 1.37$ kip $\qquad F_{AC} = 744.11$ lb $= 0.744$ kip **Ans**

$F_{AD} = 1703.62$ lb $= 1.70$ kip **Ans**

3–51. Determine the force in each cable needed to support the 3500-lb platform. Set $d = 4$ ft.



Cartesian Vector Notation:

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{4\mathbf{i} - 3\mathbf{j} - 10\mathbf{k}}{\sqrt{4^2 + (-3)^2 + (-10)^2}}\right) = 0.3578F_{AB}\mathbf{i} - 0.2683F_{AB}\mathbf{j} - 0.8944F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{3\mathbf{j} - 10\mathbf{k}}{\sqrt{3^2 + (-10)^2}}\right) = 0.2873F_{AC}\mathbf{j} - 0.9578F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-4\mathbf{i} + 1\mathbf{j} - 10\mathbf{k}}{\sqrt{(-4)^2 + 1^2 + (-10)^2}}\right) = -0.3698F_{AD}\mathbf{i} + 0.09245F_{AD}\mathbf{j} - 0.9245F_{AD}\mathbf{k}$$

$$\mathbf{F} = \{3500\mathbf{k}\}\ \text{lb}$$

Equations of Equilibrium:

$$\Sigma\mathbf{F} = 0; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{F} = 0$$

$$(0.3578F_{AB} - 0.3698F_{AD})\mathbf{i} + (-0.2683F_{AB} + 0.2873F_{AC} + 0.09245F_{AD})\mathbf{j} + (-0.8944F_{AB} - 0.9578F_{AC} - 0.9245F_{AD} + 3500)\mathbf{k} = 0$$

Equating **i**, **j** and **k** components, we have

$$0.3578F_{AB} - 0.3698F_{AD} = 0 \qquad [1]$$

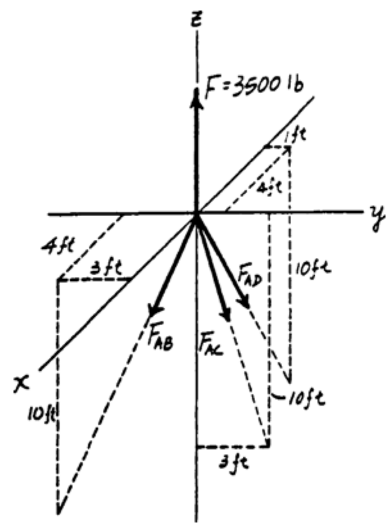
$$-0.2683F_{AB} + 0.2873F_{AC} + 0.09245F_{AD} = 0 \qquad [2]$$

$$-0.8944F_{AB} - 0.9578F_{AC} - 0.9245F_{AD} + 3500 = 0 \qquad [3]$$

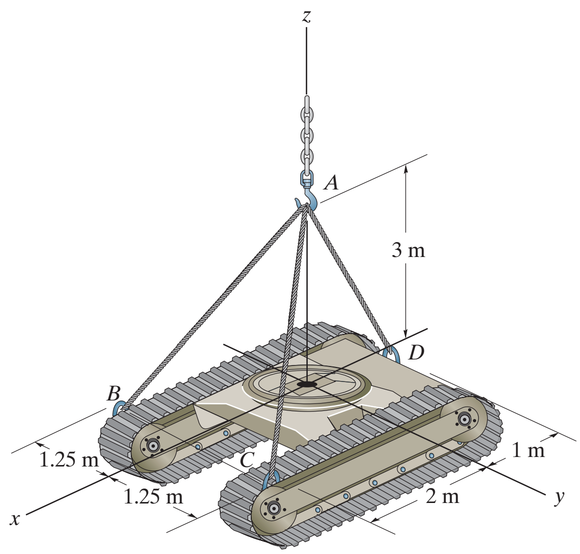
Solving Eqs. [1], [2] and [3] yields

$F_{AB} = 1467.42\ \text{lb} = 1.47\ \text{kip}$ $\quad F_{AC} = 913.53\ \text{lb} = 0.914\ \text{kip}$ **Ans**

$F_{AD} = 1419.69\ \text{lb} = 1.42\ \text{kip}$ **Ans**



***3–52.** Determine the force in each of the three cables needed to lift the tractor which has a mass of 8 Mg.



Cartesian Vector Notation :

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{2\mathbf{i} - 1.25\mathbf{j} - 3\mathbf{k}}{\sqrt{2^2 + (-1.25)^2 + (-3)^2}}\right) = 0.5241F_{AB}\mathbf{i} - 0.3276F_{AB}\mathbf{j} - 0.7861F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{2\mathbf{i} + 1.25\mathbf{j} - 3\mathbf{k}}{\sqrt{2^2 + 1.25^2 + (-3)^2}}\right) = 0.5241F_{AC}\mathbf{i} + 0.3276F_{AC}\mathbf{j} - 0.7861F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-1\mathbf{i} - 3\mathbf{k}}{\sqrt{(-1)^2 + (-3)^2}}\right) = -0.3162F_{AD}\mathbf{i} - 0.9487F_{AD}\mathbf{k}$$

$$\mathbf{F} = \{78.48\mathbf{k}\}\ \text{kN}$$

Equations of Equilibrium :

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{F} = \mathbf{0}$$

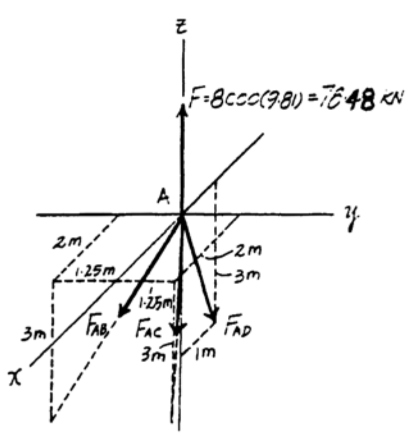
$$(0.5241F_{AB} + 0.5241F_{AC} - 0.3162F_{AD})\mathbf{i} + (-0.3276F_{AB} + 0.3276F_{AC})\mathbf{j}$$
$$+ (-0.7861F_{AB} - 0.7861F_{AC} - 0.9487F_{AD} + 78.48)\mathbf{k} = \mathbf{0}$$

Equating i, j and k components, we have

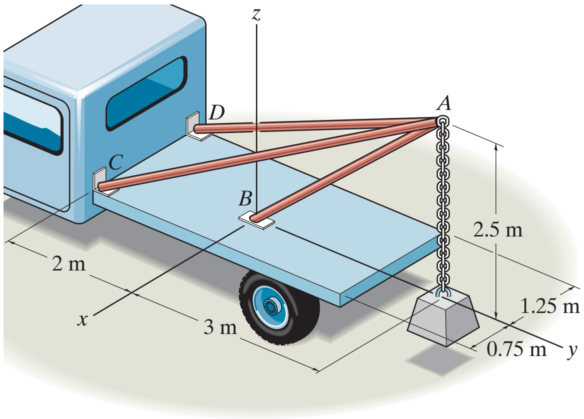
$$0.5241F_{AB} + 0.5241F_{AC} - 0.3162F_{AD} = 0 \qquad [1]$$
$$-0.3276F_{AB} + 0.3276F_{AC} = 0 \qquad [2]$$
$$-0.7861F_{AB} - 0.7861F_{AC} - 0.9487F_{AD} + 78.48 = 0 \qquad [3]$$

Solving Eqs. [1], [2] and [3] yields

$$F_{AB} = F_{AC} = 16.6\ \text{kN} \qquad F_{AD} = 55.2\ \text{kN} \qquad \textbf{Ans}$$



•3–53. Determine the force acting along the axis of each of the three struts needed to support the 500-kg block.



$$\mathbf{F}_B = F_B\left(\frac{3\,\mathbf{j} + 2.5\,\mathbf{k}}{3.905}\right)$$

$$= 0.7682\,F_B\,\mathbf{j} + 0.6402\,F_B\,\mathbf{k}$$

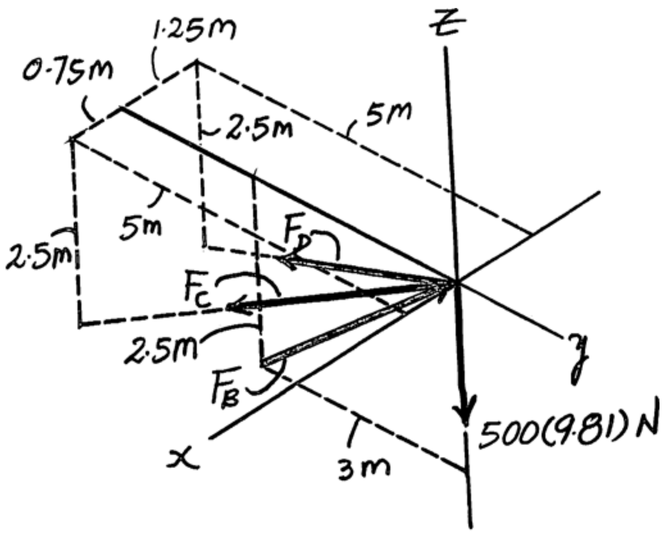
$$\mathbf{F}_C = F_C\left(\frac{0.75\,\mathbf{i} - 5\,\mathbf{j} - 2.5\,\mathbf{k}}{5.640}\right)$$

$$= 0.1330\,F_C\,\mathbf{i} - 0.8865\,F_C\,\mathbf{j} - 0.4432\,F_C\,\mathbf{k}$$

$$\mathbf{F}_D = F_D\left(\frac{-1.25\,\mathbf{i} - 5\,\mathbf{j} - 2.5\,\mathbf{k}}{5.728}\right)$$

$$= -0.2182\,F_D\,\mathbf{i} - 0.8729\,F_D\,\mathbf{j} - 0.4364\,F_D\,\mathbf{k}$$

$$\mathbf{W} = -500(9.81)\,\mathbf{k} = -4905\,\mathbf{k}$$



$\Sigma \mathbf{F} = 0;\quad \mathbf{F}_B + \mathbf{F}_C + \mathbf{F}_D + \mathbf{W} = 0$

$\Sigma F_x = 0;\quad 0.1330\,F_C - 0.2182\,F_D = 0$

$\Sigma F_y = 0;\quad 0.7682\,F_B - 0.8865\,F_C - 0.8729\,F_D = 0$

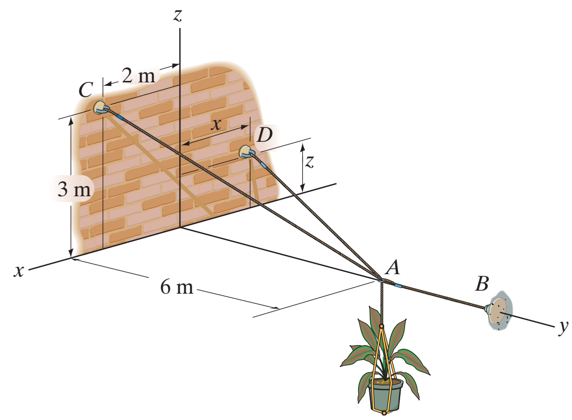
$\Sigma F_z = 0;\quad 0.6402\,F_B - 0.4432\,F_C - 0.4364\,F_D - 4905 = 0$

$F_B = 19.2\text{ kN}$ **Ans**

$F_C = 10.4\text{ kN}$ **Ans**

$F_D = 6.32\text{ kN}$ **Ans**

3–54. If the mass of the flowerpot is 50 kg, determine the tension developed in each wire for equilibrium. Set $x = 1.5$ m and $z = 2$ m.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{j}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(2-0)\mathbf{i}+(-6-0)\mathbf{j}+(3-0)\mathbf{k}}{\sqrt{(2-0)^2+(-6-0)^2+(3-0)^2}}\right] = \frac{2}{7}F_{AC}\,\mathbf{i}-\frac{6}{7}F_{AC}\,\mathbf{j}+\frac{3}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(-1.5-0)\mathbf{i}+(-6-0)\mathbf{j}+(2-0)\mathbf{k}}{\sqrt{(-1.5-0)^2+(-6-0)^2+(2-0)^2}}\right] = -\frac{3}{13}F_{AD}\,\mathbf{i}-\frac{12}{13}F_{AD}\,\mathbf{j}+\frac{4}{13}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = [-50(9.81)\mathbf{k}]\text{ N} = [-490.5\mathbf{k}]\text{ N}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = 0; \quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{W} = \mathbf{0}$$

$$F_{AB}\,\mathbf{j}+\left(\frac{2}{7}F_{AC}\,\mathbf{i}-\frac{6}{7}F_{AC}\,\mathbf{j}+\frac{3}{7}F_{AC}\,\mathbf{k}\right)+\left(-\frac{3}{13}F_{AD}\,\mathbf{i}-\frac{12}{13}F_{AD}\,\mathbf{j}+\frac{4}{13}F_{AD}\,\mathbf{k}\right)+(-490.5\mathbf{k}) = \mathbf{0}$$

$$\left(\frac{2}{7}F_{AC}-\frac{3}{13}F_{AD}\right)\mathbf{i}+\left(F_{AB}-\frac{6}{7}F_{AC}-\frac{12}{13}F_{AD}\right)\mathbf{j}+\left(\frac{3}{7}F_{AC}+\frac{4}{13}F_{AD}-490.5\right)\mathbf{k} = 0$$

Equating the **i**, **j**, and **k** components yields

$$\frac{2}{7}F_{AC}-\frac{3}{13}F_{AD} = 0 \qquad (1)$$

$$F_{AB}-\frac{6}{7}F_{AC}-\frac{12}{13}F_{AD} = 0 \qquad (2)$$

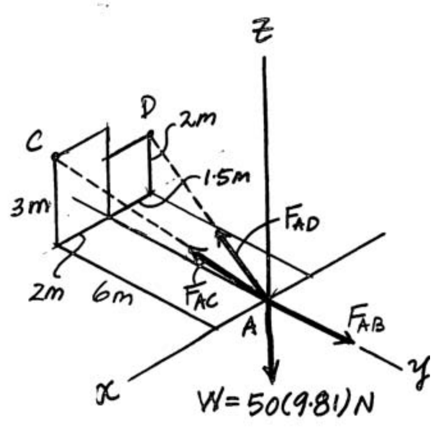
$$\frac{3}{7}F_{AC}+\frac{4}{13}F_{AD}-490.5 = 0 \qquad (3)$$

Solving Eqs. (1) through (3) yields

$F_{AB} = 1211.82\text{ N} = 1.21\text{ kN}$ **Ans.**

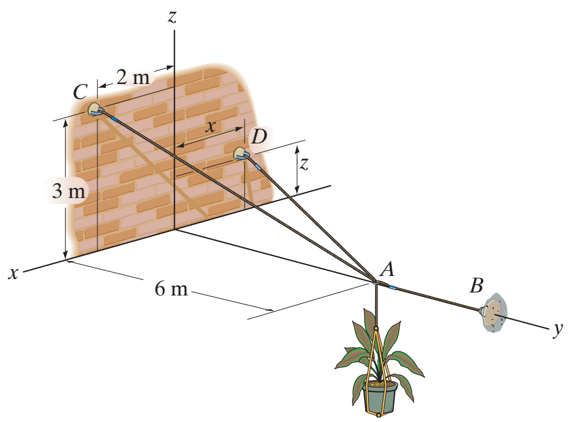
$F_{AC} = 606\text{ N}$ **Ans.**

$F_{AD} = 750\text{ N}$ **Ans.**



(a)

3–55. If the mass of the flowerpot is 50 kg, determine the tension developed in each wire for equilibrium. Set $x = 2$ m and $z = 1.5$ m.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\,\mathbf{j}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(2-0)\mathbf{i}+(-6-0)\mathbf{j}+(3-0)\mathbf{k}}{\sqrt{(2-0)^2+(-6-0)^2+(3-0)^2}}\right] = \frac{2}{7}F_{AC}\,\mathbf{i}-\frac{6}{7}F_{AC}\,\mathbf{j}+\frac{3}{7}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(-2-0)\mathbf{i}+(-6-0)\mathbf{j}+(1.5-0)\mathbf{k}}{\sqrt{(-2-0)^2+(-6-0)^2+(1.5-0)^2}}\right] = -\frac{4}{13}F_{AD}\,\mathbf{i}-\frac{12}{13}F_{AD}\,\mathbf{j}+\frac{3}{13}F_{AD}\,\mathbf{k}$$

$$\mathbf{W} = [-50(9.81)\mathbf{k}]\text{ N} = [-490.5\mathbf{k}]\text{ N}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0};\quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{W} = \mathbf{0}$$

$$F_{AB}\,\mathbf{j}+\left(\frac{2}{7}F_{AC}\mathbf{i}-\frac{6}{7}F_{AC}\mathbf{j}+\frac{3}{7}F_{AC}\mathbf{k}\right)+\left(-\frac{4}{13}F_{AD}\mathbf{i}-\frac{12}{13}F_{AD}\mathbf{j}+\frac{3}{13}F_{AD}\mathbf{k}\right)+(-490.5\mathbf{k}) = \mathbf{0}$$

$$\left(\frac{2}{7}F_{AC}-\frac{4}{13}F_{AD}\right)\mathbf{i}+\left(F_{AB}-\frac{6}{7}F_{AC}-\frac{12}{13}F_{AD}\right)\mathbf{j}+\left(\frac{3}{7}F_{AC}+\frac{3}{13}F_{AD}-490.5\right)\mathbf{k} = \mathbf{0}$$

Equating the **i**, **j**, and **k** components yields

$$\frac{2}{7}F_{AC}-\frac{4}{13}F_{AD} = 0 \qquad (1)$$

$$F_{AB}-\frac{6}{7}F_{AC}-\frac{12}{13}F_{AD} = 0 \qquad (2)$$

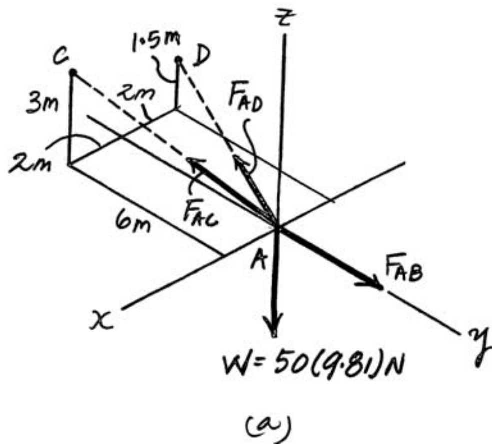
$$\frac{3}{7}F_{AC}+\frac{3}{13}F_{AD}-490.5 = 0 \qquad (3)$$

Solving Eqs. (1) through (3) yields

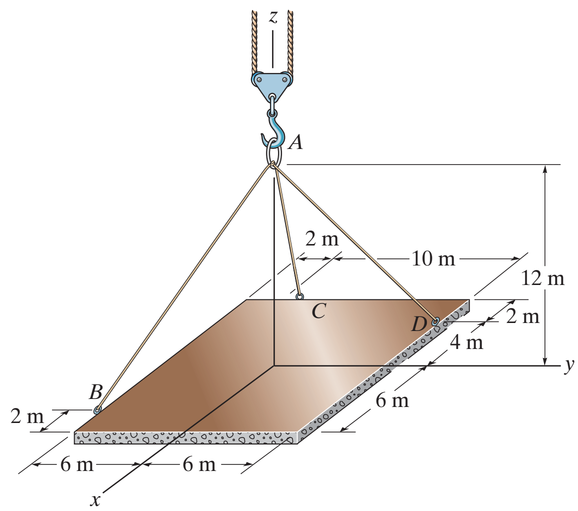
$F_{AB} = 1308\text{ N} = 1.31\text{ kN}$ **Ans.**

$F_{AC} = 763\text{ N}$ **Ans.**

$F_{AD} = 708.5\text{ N}$ **Ans.**



***3–56.** The ends of the three cables are attached to a ring at A and to the edge of a uniform 150-kg plate. Determine the tension in each of the cables for equilibrium.

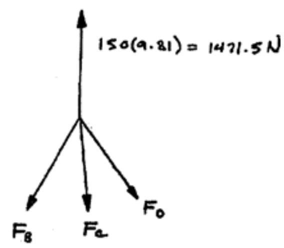


$$\mathbf{P} = 150(9.81)\mathbf{k} = 1471.5\,\mathbf{k}$$

$$\mathbf{F}_B = \frac{4}{14}F_B\,\mathbf{i} - \frac{6}{14}F_B\,\mathbf{j} - \frac{12}{14}F_B\,\mathbf{k}$$

$$\mathbf{F}_C = -\frac{6}{14}F_C\,\mathbf{i} - \frac{4}{14}F_C\,\mathbf{j} - \frac{12}{14}F_C\,\mathbf{k}$$

$$\mathbf{F}_D = -\frac{4}{14}F_D\,\mathbf{i} + \frac{6}{14}F_D\,\mathbf{j} - \frac{12}{14}F_D\,\mathbf{k}$$



$\Sigma F_x = 0;\quad \frac{4}{14}F_B - \frac{6}{14}F_C - \frac{4}{14}F_D = 0$

$\Sigma F_y = 0;\quad -\frac{6}{14}F_B - \frac{4}{14}F_C + \frac{6}{14}F_D = 0$

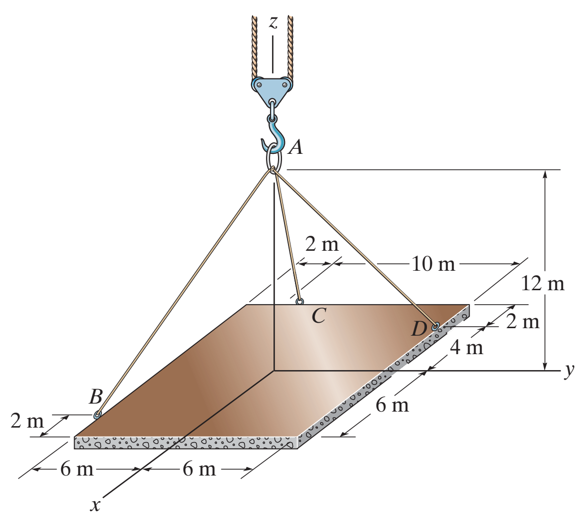
$\Sigma F_z = 0;\quad -\frac{12}{14}F_B - \frac{12}{14}F_C - \frac{12}{14}F_D + 1471.5 = 0$

$F_B = 858\text{ N}$ **Ans**

$F_C = 0$ **Ans**

$F_D = 858\text{ N}$ **Ans**

•3–57. The ends of the three cables are attached to a ring at A and to the edge of the uniform plate. Determine the largest mass the plate can have if each cable can support a maximum tension of 15 kN.

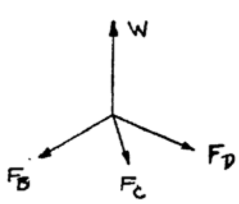


$$\mathbf{W} = W\mathbf{k}$$

$$\mathbf{F}_B = F_B\left(\frac{4}{14}\mathbf{i} - \frac{6}{14}\mathbf{j} - \frac{12}{14}\mathbf{k}\right)$$

$$\mathbf{F}_C = F_C\left(-\frac{6}{14}\mathbf{i} - \frac{4}{14}\mathbf{j} - \frac{12}{14}\mathbf{k}\right)$$

$$\mathbf{F}_D = F_D\left(-\frac{4}{14}\mathbf{i} + \frac{6}{14}\mathbf{j} - \frac{12}{14}\mathbf{k}\right)$$



$\Sigma F_x = 0;\quad \frac{4}{14}F_B - \frac{6}{14}F_C - \frac{4}{14}F_D = 0$

$\Sigma F_y = 0;\quad -\frac{6}{14}F_B - \frac{4}{14}F_C + \frac{6}{14}F_D = 0$

$\Sigma F_z = 0;\quad -\frac{12}{14}F_B - \frac{12}{14}F_C - \frac{12}{14}F_D + W = 0$

Assume $F_B = 15$ kN. Solving,

$F_C = 0 < 15\text{ kN}$ (OK)

$F_D = 15\text{ kN}$ (OK)

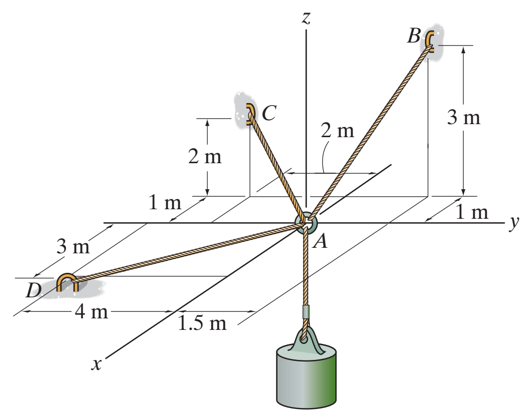
Thus,

$$-\frac{12}{14}(15) - 0 - \frac{12}{14}(15) + W = 0$$

$$W = 25.714\text{ kN}$$

$$m = \frac{W}{g} = \frac{25.714}{9.81} = 2.62\text{ Mg}$$ **Ans**

3–58. Determine the tension developed in cables AB, AC, and AD required for equilibrium of the 75-kg cylinder.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-1-0)\mathbf{i}+(1.5-0)\mathbf{j}+(3-0)\mathbf{k}}{\sqrt{(-1-0)^2+(1.5-0)^2+(3-0)^2}}\right] = -\frac{2}{7}F_{AB}\,\mathbf{i}+\frac{3}{7}F_{AB}\,\mathbf{j}+\frac{6}{7}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-1-0)\mathbf{i}+(-2-0)\mathbf{j}+(2-0)\mathbf{k}}{\sqrt{(-1-0)^2+(-2-0)^2+(2-0)^2}}\right] = -\frac{1}{3}F_{AC}\,\mathbf{i}-\frac{2}{3}F_{AC}\,\mathbf{j}+\frac{2}{3}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(3-0)\mathbf{i}+(-4-0)\mathbf{j}+(0-0)\mathbf{k}}{\sqrt{(3-0)^2+(-4-0)^2+(0-0)^2}}\right] = \frac{3}{5}F_{AD}\,\mathbf{i}-\frac{4}{5}F_{AD}\,\mathbf{j}$$

$$\mathbf{W} = [-75(9.81)\mathbf{k}]\text{N} = [-735.75\mathbf{k}]\text{N}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0}; \quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{W} = \mathbf{0}$$

$$\left(-\frac{2}{7}F_{AB}\mathbf{i}+\frac{3}{7}F_{AB}\mathbf{j}+\frac{6}{7}F_{AB}\mathbf{k}\right)+\left(-\frac{1}{3}F_{AC}\mathbf{i}-\frac{2}{3}F_{AC}\mathbf{j}+\frac{2}{3}F_{AC}\mathbf{k}\right)+\left(\frac{3}{5}F_{AD}\mathbf{i}-\frac{4}{5}F_{AD}\mathbf{j}\right)+(-735.75\mathbf{k}) = \mathbf{0}$$

$$\left(-\frac{2}{7}F_{AB}-\frac{1}{3}F_{AC}+\frac{3}{5}F_{AD}\right)\mathbf{i}+\left(\frac{3}{7}F_{AB}-\frac{2}{3}F_{AC}-\frac{4}{5}F_{AD}\right)\mathbf{j}+\left(\frac{6}{7}F_{AB}+\frac{2}{3}F_{AC}-735.75\right)\mathbf{k} = \mathbf{0}$$

Equating the **i**, **j**, and **k** components yields

$$-\frac{2}{7}F_{AB}-\frac{1}{3}F_{AC}+\frac{3}{5}F_{AD} = 0 \quad (1)$$

$$\frac{3}{7}F_{AB}-\frac{2}{3}F_{AC}-\frac{4}{5}F_{AD} = 0 \quad (2)$$

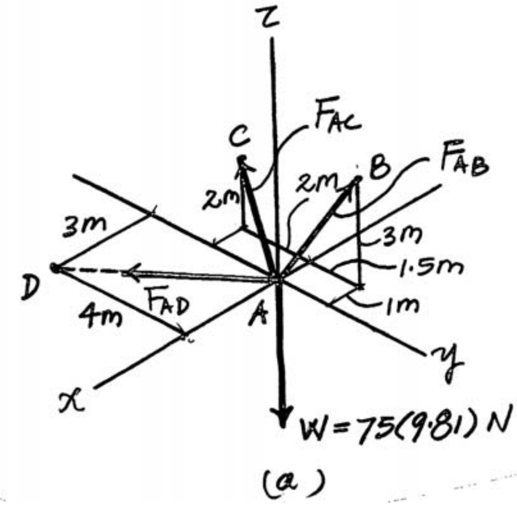
$$\frac{6}{7}F_{AB}+\frac{2}{3}F_{AC}-735.75 = 0 \quad (3)$$

Solving Eqs. (1) through (3) yields

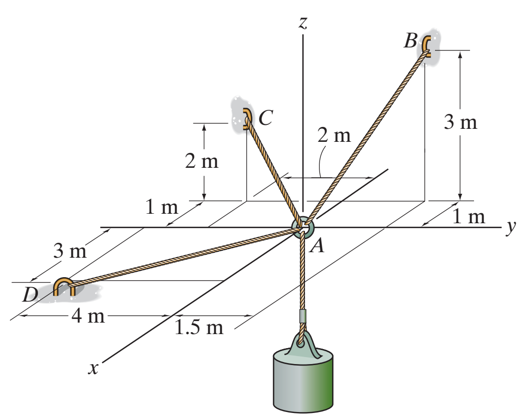
$F_{AB} = 831\text{ N}$ **Ans.**

$F_{AC} = 35.6\text{ N}$ **Ans.**

$F_{AD} = 415\text{ N}$ **Ans.**



3–59. If each cable can withstand a maximum tension of 1000 N, determine the largest mass of the cylinder for equilibrium.



Force Vectors: We can express each of the forces on the free-body diagram shown in Fig. (*a*) in Cartesian vector form as

$$\mathbf{F}_{AB} = F_{AB}\left[\frac{(-1-0)\mathbf{i}+(1.5-0)\mathbf{j}+(3-0)\mathbf{k}}{\sqrt{(-1-0)^2+(1.5-0)^2+(3-0)^2}}\right] = -\frac{2}{7}F_{AB}\,\mathbf{i}+\frac{3}{7}F_{AB}\,\mathbf{j}+\frac{6}{7}F_{AB}\,\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left[\frac{(-1-0)\mathbf{i}+(-2-0)\mathbf{j}+(2-0)\mathbf{k}}{\sqrt{(-1-0)^2+(-2-0)^2+(2-0)^2}}\right] = -\frac{1}{3}F_{AC}\,\mathbf{i}-\frac{2}{3}F_{AC}\,\mathbf{j}+\frac{2}{3}F_{AC}\,\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left[\frac{(3-0)\mathbf{i}+(-4-0)\mathbf{j}+(0-0)\mathbf{k}}{\sqrt{(3-0)^2+(-4-0)^2+(0-0)^2}}\right] = \frac{3}{5}F_{AD}\,\mathbf{i}-\frac{4}{5}F_{AD}\,\mathbf{j}$$

$$\mathbf{W} = -m(9.81)\mathbf{k}$$

Equations of Equilibrium: Equilibrium requires

$$\Sigma\mathbf{F} = \mathbf{0};\quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{W} = \mathbf{0}$$

$$\left(-\frac{2}{7}F_{AB}\mathbf{i}+\frac{3}{7}F_{AB}\mathbf{j}+\frac{6}{7}F_{AB}\mathbf{k}\right)+\left(-\frac{1}{3}F_{AC}\mathbf{i}-\frac{2}{3}F_{AC}\mathbf{j}+\frac{2}{3}F_{AC}\mathbf{k}\right)+\left(\frac{3}{5}F_{AD}\mathbf{i}-\frac{4}{5}F_{AD}\mathbf{j}\right)+[-m(9.81)\mathbf{k}] = \mathbf{0}$$

$$\left(-\frac{2}{7}F_{AB}-\frac{1}{3}F_{AC}+\frac{3}{5}F_{AD}\right)\mathbf{i}+\left(\frac{3}{7}F_{AB}-\frac{2}{3}F_{AC}-\frac{4}{5}F_{AD}\right)\mathbf{j}+\left(\frac{6}{7}F_{AB}+\frac{2}{3}F_{AC}-m(9.81)\right)\mathbf{k} = \mathbf{0}$$

Equating the **i**, **j**, and **k** components yields

$$-\frac{2}{7}F_{AB}-\frac{1}{3}F_{AC}+\frac{3}{5}F_{AD} = 0 \qquad (1)$$

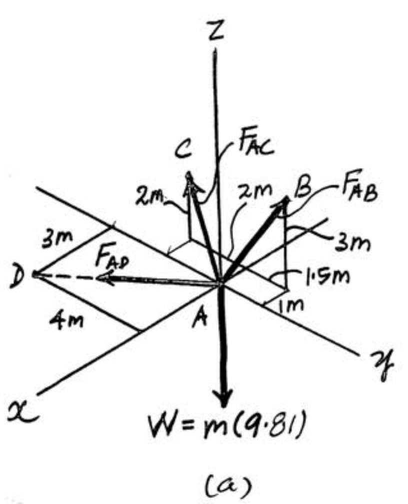
$$\frac{3}{7}F_{AB}-\frac{2}{3}F_{AC}-\frac{4}{5}F_{AD} = 0 \qquad (2)$$

$$\frac{6}{7}F_{AB}+\frac{2}{3}F_{AC}-m(9.81) = 0 \qquad (3)$$

Let us assume that cable *AB* achieves maximum tension first. Substituting $F_{AB} = 1000$ N into Eqs. (1) through (3) and solving, yields

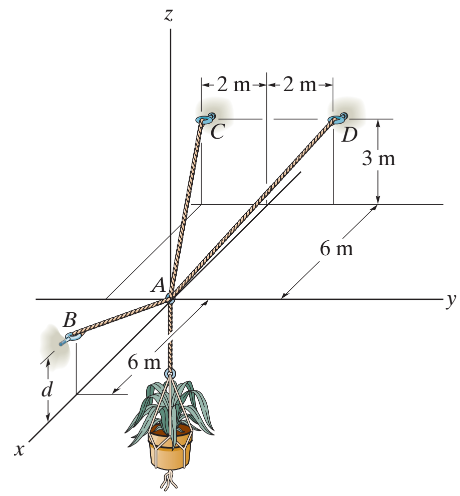
$F_{AD} = 500$ N $\qquad F_{AC} = 42.86$ N

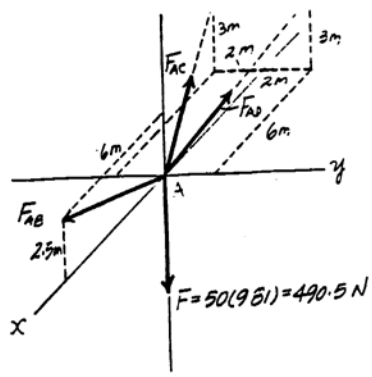
$m = 90.3$ kg $\qquad$ **Ans.**



(a)

***3–60.** The 50-kg pot is supported from A by the three cables. Determine the force acting in each cable for equilibrium. Take $d = 2.5$ m.





Cartesian Vector Notation:

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{6\mathbf{i}+2.5\mathbf{k}}{\sqrt{6^2+2.5^2}}\right) = \frac{12}{13}F_{AB}\mathbf{i}+\frac{5}{13}F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{-6\mathbf{i}-2\mathbf{j}+3\mathbf{k}}{\sqrt{(-6)^2+(-2)^2+3^2}}\right) = -\frac{6}{7}F_{AC}\mathbf{i}-\frac{2}{7}F_{AC}\mathbf{j}+\frac{3}{7}F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-6\mathbf{i}+2\mathbf{j}+3\mathbf{k}}{\sqrt{(-6)^2+2^2+3^2}}\right) = -\frac{6}{7}F_{AD}\mathbf{i}+\frac{2}{7}F_{AD}\mathbf{j}+\frac{3}{7}F_{AD}\mathbf{k}$$

$$\mathbf{F} = \{-490.5\mathbf{k}\}\text{ N}$$

Equations of Equilibrium:

$$\Sigma\mathbf{F} = 0; \qquad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AD}+\mathbf{F} = \mathbf{0}$$

$$\left(\frac{12}{13}F_{AB}-\frac{6}{7}F_{AC}-\frac{6}{7}F_{AD}\right)\mathbf{i}+\left(-\frac{2}{7}F_{AC}+\frac{2}{7}F_{AD}\right)\mathbf{j} + \left(\frac{5}{13}F_{AB}+\frac{3}{7}F_{AC}+\frac{3}{7}F_{AD}-490.5\right)\mathbf{k} = \mathbf{0}$$

Equating **i**, **j** and **k** components, we have

$$\frac{12}{13}F_{AB}-\frac{6}{7}F_{AC}-\frac{6}{7}F_{AD} = 0 \qquad [1]$$

$$-\frac{2}{7}F_{AC}+\frac{2}{7}F_{AD} = 0 \qquad [2]$$

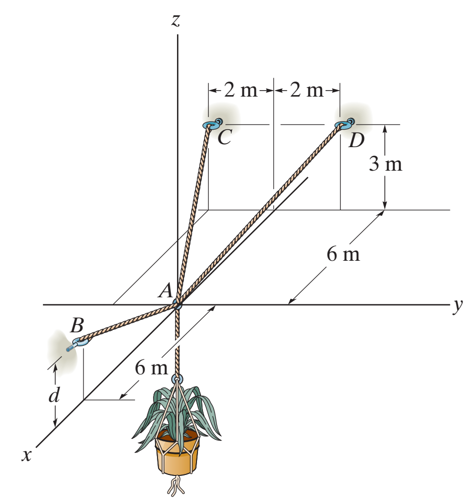
$$\frac{5}{13}F_{AB}+\frac{3}{7}F_{AC}+\frac{3}{7}F_{AD}-490.5 = 0 \qquad [3]$$

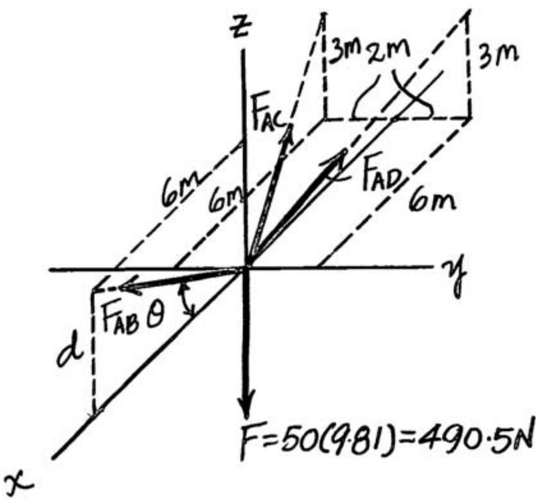
Solving Eqs. [1], [2] and [3] yields

$$F_{AC} = F_{AD} = 312\text{ N}$$

$$F_{AB} = 580\text{ N} \qquad \textbf{Ans}$$

•3–61. Determine the height d of cable AB so that the force in cables AD and AC is one-half as great as the force in cable AB. What is the force in each cable for this case? The flower pot has a mass of 50 kg.





Cartesian Vector Notation :

$$\mathbf{F}_{AB} = (F_{AB})_x\,\mathbf{i} + (F_{AB})_z\,\mathbf{k}$$

$$\mathbf{F}_{AC} = \frac{F_{AB}}{2}\left(\frac{-6\mathbf{i} - 2\mathbf{j} + 3\mathbf{k}}{\sqrt{(-6)^2 + (-2)^2 + 3^2}}\right) = -\frac{3}{7}F_{AB}\mathbf{i} - \frac{1}{7}F_{AB}\mathbf{j} + \frac{3}{14}F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AD} = \frac{F_{AB}}{2}\left(\frac{-6\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}}{\sqrt{(-6)^2 + 2^2 + 3^2}}\right) = -\frac{3}{7}F_{AB}\mathbf{i} + \frac{1}{7}F_{AB}\mathbf{j} + \frac{3}{14}F_{AB}\mathbf{k}$$

$$\mathbf{F} = \{-490.5\mathbf{k}\}\ \text{N}$$

Equations of Equilibrium :

$$\Sigma\mathbf{F} = 0; \quad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{F} = \mathbf{0}$$

$$\left((F_{AB})_x - \frac{3}{7}F_{AB} - \frac{3}{7}F_{AB}\right)\mathbf{i} + \left(-\frac{1}{7}F_{AB} + \frac{1}{7}F_{AB}\right)\mathbf{j} + \left((F_{AB})_z + \frac{3}{14}F_{AB} + \frac{3}{14}F_{AB} - 490.5\right)\mathbf{k} = \mathbf{0}$$

Equating **i**, **j** and **k** components, we have

$$(F_{AB})_x - \frac{3}{7}F_{AB} - \frac{3}{7}F_{AB} = 0 \qquad (F_{AB})_x = \frac{6}{7}F_{AB} \qquad [1]$$

$$-\frac{1}{7}F_{AB} + \frac{1}{7}F_{AB} = 0 \qquad \textit{(Satisfied!)}$$

$$(F_{AB})_z + \frac{3}{14}F_{AB} + \frac{3}{14}F_{AB} - 490.5 = 0 \qquad (F_{AB})_z = 490.5 - \frac{3}{7}F_{AB} \qquad [2]$$

However, $F_{AB}^2 = (F_{AB})_x^2 + (F_{AB})_z^2$, then substitute Eqs. [1] and [2] into this expression yields

$$F_{AB}^2 = \left(\frac{6}{7}F_{AB}\right)^2 + \left(490.5 - \frac{3}{7}F_{AB}\right)^2$$

Solving for positive root, we have

$$F_{AB} = 519.79\ \text{N} = 520\ \text{N} \qquad \textbf{Ans}$$

Thus, $$F_{AC} = F_{AD} = \frac{1}{2}(519.79) = 260\ \text{N} \qquad \textbf{Ans}$$

Also,

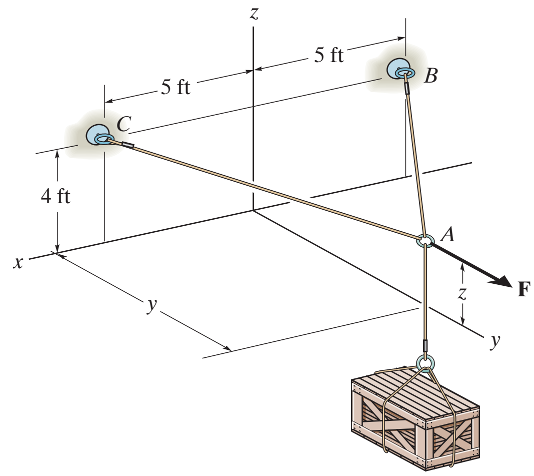
$$(F_{AB})_x = \frac{6}{7}(519.79) = 445.53\ \text{N}$$

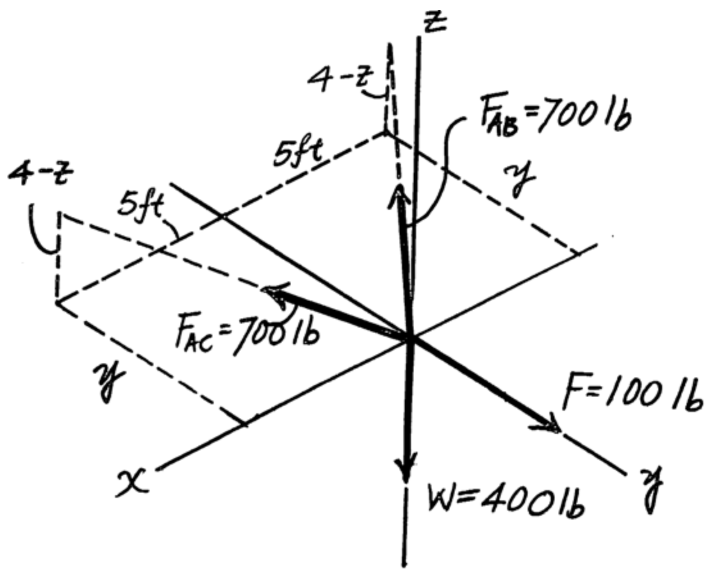
$$(F_{AB})_z = 490.5 - \frac{3}{7}(519.79) = 267.73\ \text{N}$$

then, $$\theta = \tan^{-1}\left[\frac{(F_{AB})_z}{(F_{AB})_x}\right] = \tan^{-1}\left(\frac{267.73}{445.53}\right) = 31.00^\circ$$

$$d = 6\tan\theta = 6\tan 31.00^\circ = 3.61\ \text{m} \qquad \textbf{Ans}$$

3–62. A force of $F = 100$ lb holds the 400-lb crate in equilibrium. Determine the coordinates $(0, y, z)$ of point A if the tension in cords AC and AB is 700 lb each.





$$\mathbf{F}_{AC} = 700\left(\frac{5\mathbf{i} - y\mathbf{j} + (4-z)\mathbf{k}}{\sqrt{5^2 + (-y)^2 + (4-z)^2}}\right)$$

$$\mathbf{F}_{AB} = 700\left(\frac{-5\mathbf{i} - y\mathbf{j} + (4-z)\mathbf{k}}{\sqrt{(-5)^2 + (-y)^2 + (4-z)^2}}\right)$$

$\mathbf{F} = \{100\,\mathbf{j}\}$ lb $\quad \mathbf{W} = \{-400\,\mathbf{k}\}$ lb

$\Sigma F_x = 0;\quad \dfrac{3500}{\sqrt{25 + y^2 + (4-z)^2}} + \dfrac{-3500}{\sqrt{25 + y^2 + (4-z)^2}} = 0$

$\Sigma F_y = 0;\quad \dfrac{-700y}{\sqrt{25 + y^2 + (4-z)^2}} + \dfrac{-700y}{\sqrt{25 + y^2 + (4-z)^2}} + 100 = 0 \qquad (1)$

$\Sigma F_z = 0;\quad \dfrac{700(4-z)}{\sqrt{25 + y^2 + (4-z)^2}} + \dfrac{700(4-z)}{\sqrt{25 + y^2 + (4-z)^2}} - 400 = 0 \qquad (2)$

$1400\,y = 100\sqrt{25 + y^2 + (4-z)^2}$

$1400(4-z) = 400\sqrt{25 + y^2 + (4-z)^2}$

$\dfrac{y}{4-z} = \dfrac{1}{4} \qquad 4\,y = 4 - z$

Thus,

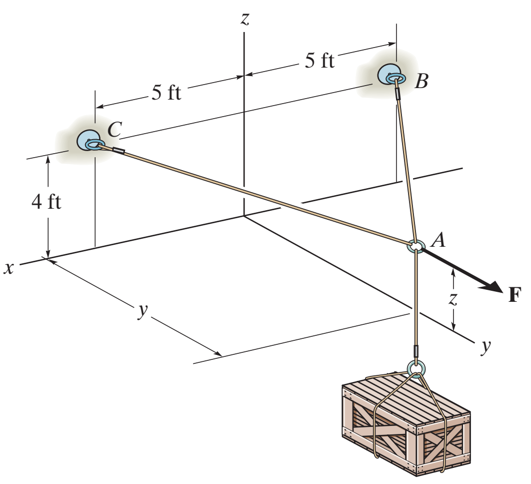
$1400\,y = 100\sqrt{25 + y^2 + 16\,y^2}$

$196\,y^2 = 25 + 17\,y^2$

$y = 0.3737$ ft $= 0.374$ ft **Ans**

$4(0.3737) = 4 - z;\quad z = 2.51$ ft **Ans**

3–63. If the maximum allowable tension in cables *AB* and *AC* is 500 lb, determine the maximum height *z* to which the 200-lb crate can be lifted. What horizontal force *F* must be applied? Take $y = 8$ ft.



$$\Sigma F_y = 0; \quad -2\left[500\left(\frac{8}{\sqrt{5^2 + 8^2 + (4-z)^2}}\right)\right] + F = 0 \qquad (1)$$

$$\Sigma F_z = 0; \quad 2\left[500\left(\frac{4-z}{\sqrt{5^2 + 8^2 + (4-z)^2}}\right)\right] - 200 = 0 \qquad (2)$$

Dividing Eq. (2) by Eq. (1),

$$\frac{4-z}{8} = \frac{200}{F}$$

$$(4 - z) = \frac{1600}{F}$$

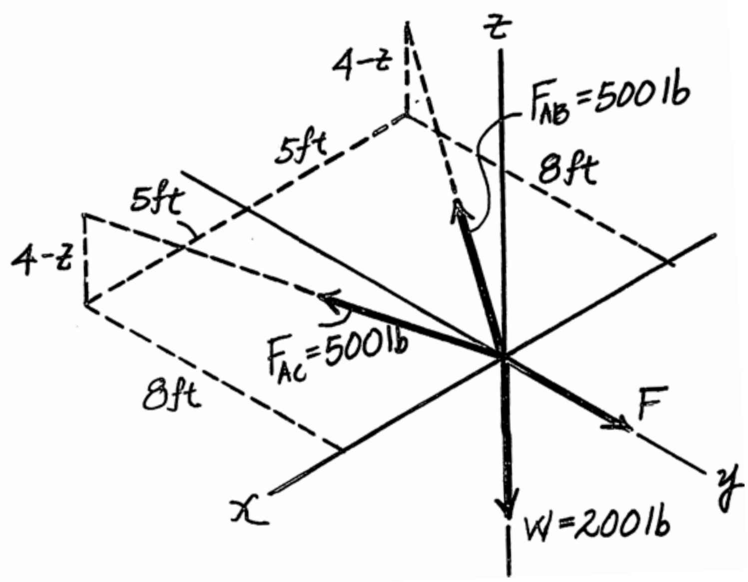
From Eq. (1):

$$\frac{8000}{F} = \sqrt{89 + \left(\frac{1600}{F}\right)^2}$$

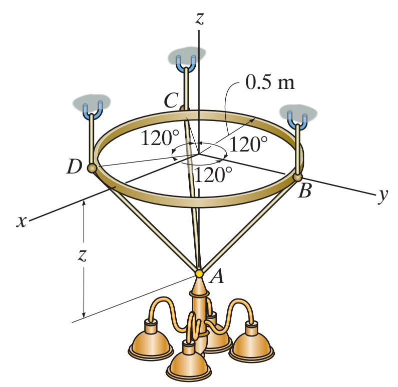
$$\left(\frac{8000}{F}\right)^2 = 89 + \left(\frac{1600}{F}\right)^2$$

$F = 831$ lb **Ans**

$z = 2.07$ ft **Ans**



***3–64.** The thin ring can be adjusted vertically between three equally long cables from which the 100-kg chandelier is suspended. If the ring remains in the horizontal plane and $z = 600$ mm, determine the tension in each cable.



Geometry: Referring to the geometry of the free - body diagram shown in Fig. (*a*), the lengths of cables *AB*, *AC*, and *AD* are all $l = \sqrt{0.5^2 + 0.6^2} = \sqrt{0.61}$ m.

Equations of Equilibrium: Equilibrium requires

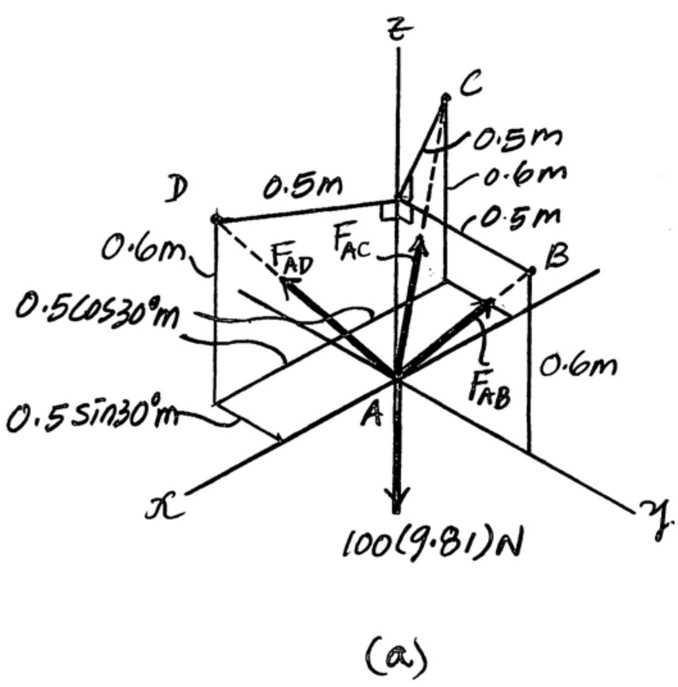
$$\Sigma F_x = 0; \quad F_{AD}\left(\frac{0.5\cos 30^\circ}{\sqrt{0.61}}\right) - F_{AC}\left(\frac{0.5\cos 30^\circ}{\sqrt{0.61}}\right) = 0 \quad F_{AD} = F_{AC} = F$$

$$\Sigma F_y = 0; \quad F_{AB}\left(\frac{0.5}{\sqrt{0.61}}\right) - 2\left[F\left(\frac{0.5\sin 30^\circ}{\sqrt{0.61}}\right)\right] = 0 \qquad F_{AB} = F$$

Thus, cables *AB*, *AC*, and *AD* all develop the same tension.

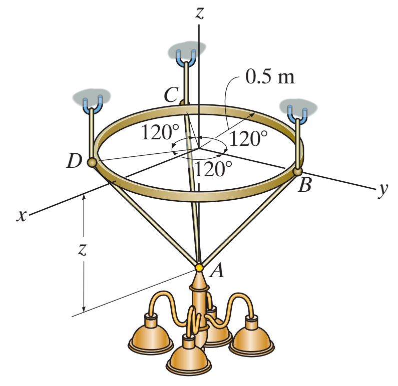
$$\Sigma F_z = 0; \quad 3F\left(\frac{0.6}{\sqrt{0.61}}\right) - 100(9.81) = 0$$

$$F_{AB} = F_{AC} = F_{AD} = 426 \text{ N} \qquad \textbf{Ans.}$$



(a)

•3–65. The thin ring can be adjusted vertically between three equally long cables from which the 100-kg chandelier is suspended. If the ring remains in the horizontal plane and the tension in each cable is not allowed to exceed 1 kN, determine the smallest allowable distance z required for equilibrium.



Geometry: Referring to the geometry of the free-body diagram shown in Fig. (a), the lengths of cables AB, AC, and AD are all $l = \sqrt{0.5^2 + z^2}$.

Equations of Equilibrium: Equilibrium requires

$$\Sigma F_x = 0; \quad F_{AD}\left(\frac{0.5\cos 30°}{\sqrt{0.5^2 + z^2}}\right) - F_{AC}\left(\frac{0.5\cos 30°}{\sqrt{0.5^2 + z^2}}\right) = 0 \qquad F_{AD} = F_{AC} = F$$

$$\Sigma F_y = 0; \quad F_{AB}\left(\frac{0.5}{\sqrt{0.5^2 + z^2}}\right) - 2\left[F\left(\frac{0.5\sin 30°}{\sqrt{0.5^2 + z^2}}\right)\right] = 0 \qquad F_{AB} = F$$

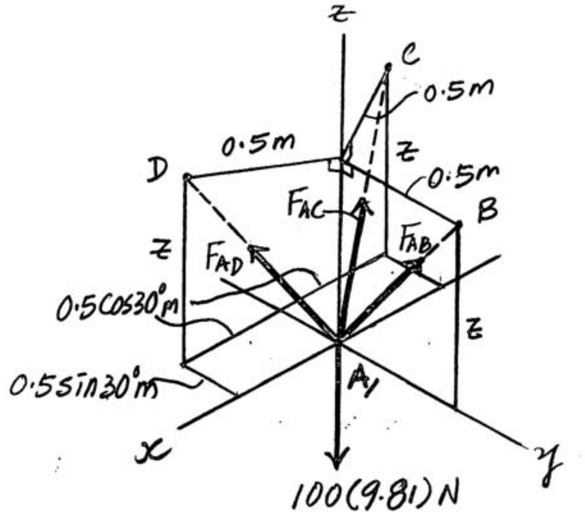
Thus, cables AB, AC, and AD all develop the same tension.

$$\Sigma F_z = 0; \quad 3F\left(\frac{z}{\sqrt{0.5^2 + z^2}}\right) - 100(9.81) = 0$$

Cables AB, AC, and AD will also achieve maximum tension simultaneously. Substituting $F = 1000$ N, we obtain

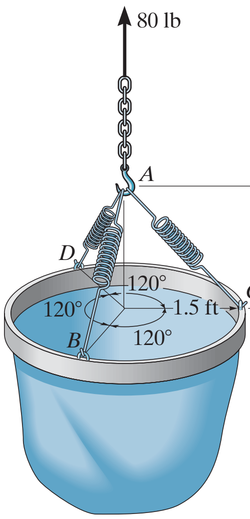
$$3(1000)\left(\frac{z}{\sqrt{0.5^2 + z^2}}\right) - 100(9.81) = 0$$

$$z = 0.1730 \text{ m} = 173 \text{ mm} \qquad \textbf{Ans.}$$



(a)

3–66. The bucket has a weight of 80 lb and is being hoisted using three springs, each having an unstretched length of $l_0 = 1.5$ ft and stiffness of $k = 50$ lb/ft. Determine the vertical distance d from the rim to point A for equilibrium.



$\Sigma F_z = 0;$

$$80 - \left(\frac{3d}{\sqrt{d^2 + (1.5)^2}}\right) F = 0$$

$$80 - \frac{3d}{\sqrt{d^2 + (1.5)^2}}\left[50\left(\sqrt{d^2 + (1.5)^2} - 1.5\right)\right] = 0$$

$$\frac{d}{\sqrt{d^2 + (1.5)^2}}\left(\sqrt{d^2 + (1.5)^2} - 1.5\right) = 0.5333$$

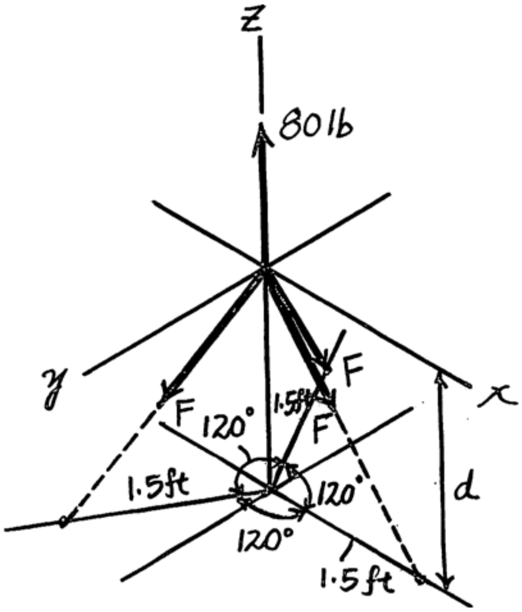
$$d\sqrt{d^2 + (1.5)^2} - 1.5d = 0.5333\sqrt{d^2 + (1.5)^2}$$

$$\sqrt{d^2 + (1.5)^2}\,(d - 0.5333) = 1.5d$$

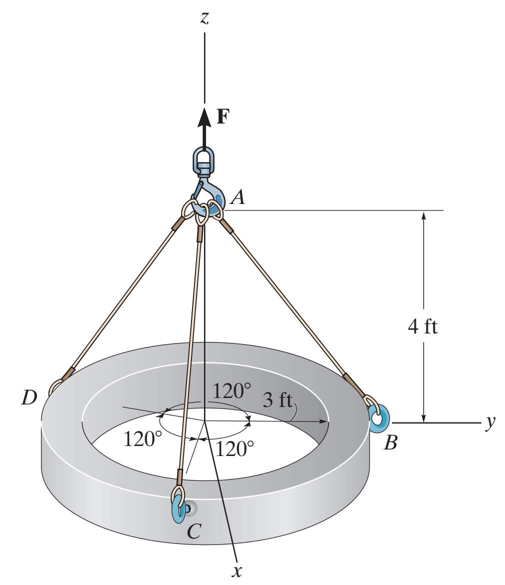
$$\left[d^2 + (1.5)^2\right]\left[d^2 - 2d\,(0.5333) + (0.5333)^2\right] = (1.5)^2 d^2$$

$$d^4 - 1.067d^3 + 0.284d^2 - 2.4d + 0.64 = 0$$

$$d = 1.64 \text{ ft} \qquad \textbf{Ans}$$



3–67. Three cables are used to support a 900-lb ring. Determine the tension in each cable for equilibrium.



Cartesian Vector Notation :

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{3\mathbf{j}-4\mathbf{k}}{\sqrt{3^2+(-4)^2}}\right) = 0.6F_{AB}\mathbf{j} - 0.8F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{3\cos 30°\mathbf{i} - 3\sin 30°\mathbf{j} - 4\mathbf{k}}{\sqrt{(3\cos 30°)^2+(-3\sin 30°)^2+(-4)^2}}\right)$$
$$= 0.5196F_{AC}\mathbf{i} - 0.3F_{AC}\mathbf{j} - 0.8F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AD} = F_{AD}\left(\frac{-3\cos 30°\mathbf{i} - 3\sin 30°\mathbf{j} - 4\mathbf{k}}{\sqrt{(-3\cos 30°)^2+(-3\sin 30°)^2+(-4)^2}}\right)$$
$$= -0.5196F_{AD}\mathbf{i} - 0.3F_{AD}\mathbf{j} - 0.8F_{AD}\mathbf{k}$$

$$\mathbf{F} = \{900\mathbf{k}\}\text{ lb}$$

Equations of Equilibrium :

$$\Sigma\mathbf{F} = \mathbf{0}; \qquad \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{F} = \mathbf{0}$$

$$(0.5196F_{AC} - 0.5196F_{AD})\mathbf{i} + (0.6F_{AB} - 0.3F_{AC} - 0.3F_{AD})\mathbf{j} + (-0.8F_{AB} - 0.8F_{AC} - 0.8F_{AD} + 900)\mathbf{k} = \mathbf{0}$$

Equating **i**, **j** and **k** components, we have

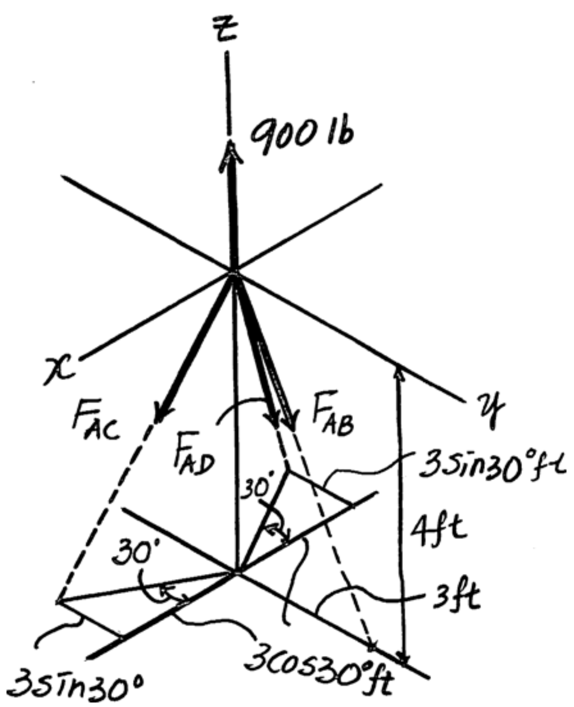
$$0.5196F_{AC} - 0.5196F_{AD} = 0 \qquad [1$$
$$0.6F_{AB} - 0.3F_{AC} - 0.3F_{AD} = 0 \qquad [2$$
$$-0.8F_{AB} - 0.8F_{AC} - 0.8F_{AD} + 900 = 0 \qquad [3$$

Solving Eqs. [1], [2] and [3] yields

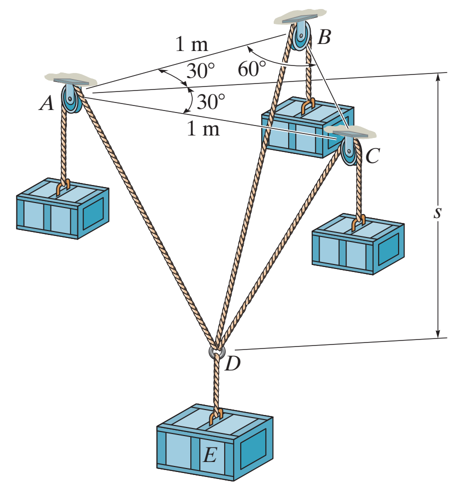
$$F_{AB} = F_{AC} = F_{AD} = 375\text{ lb} \qquad \textbf{Ans}$$

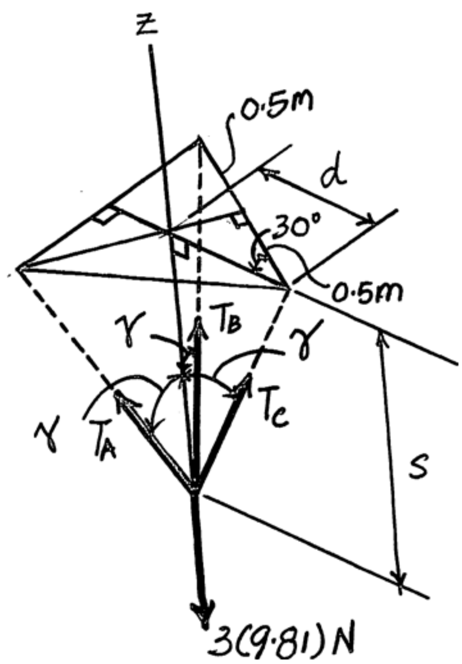
This problem also can be easily solved if one realizes that due to symmetry all cables are subjected to a same tensile force, that is $F_{AB} = F_{AC} = F_{AD} = F$. Summing forces along z axis yields

$$\Sigma F_z = 0; \qquad 900 - 3F\left(\frac{4}{5}\right) = 0 \qquad F = 375\text{ lb}$$



***3–68.** The three outer blocks each have a mass of 2 kg, and the central block E has a mass of 3 kg. Determine the sag s for equilibrium of the system.





$T_A = T_B = T_C = 2\,(9.81)$

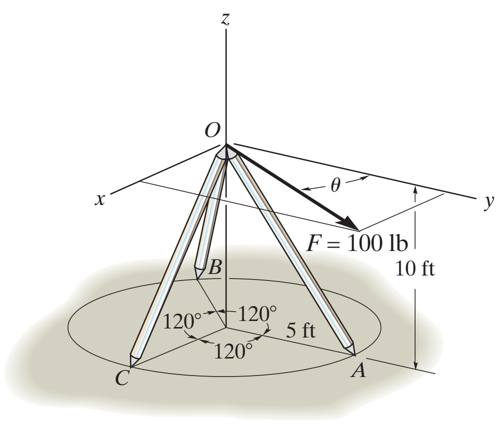
$\Sigma F_z = 0; \quad 3\,(2\,(9.81))\cos\gamma - 3\,(9.81) = 0$

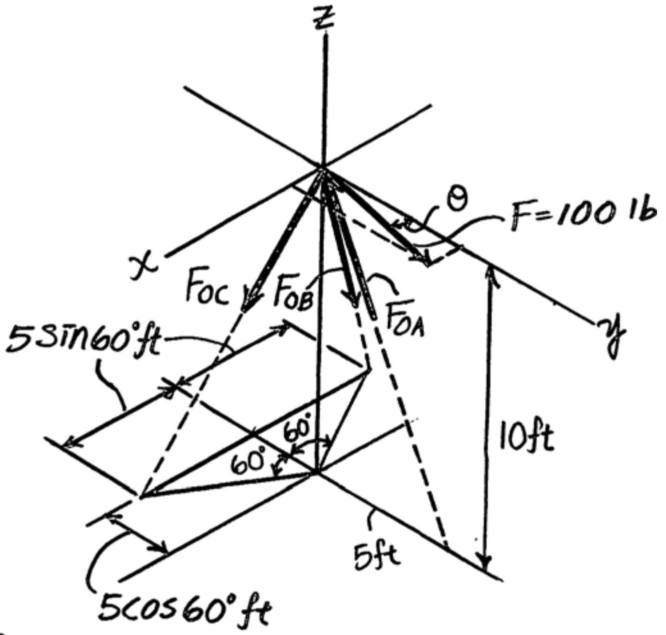
$\cos\gamma = 0.5; \quad \gamma = 60°$

$d = \dfrac{0.5}{\cos 30°} = 0.577\text{ m}$

$s = \dfrac{0.577}{\tan 60°} = 0.333\text{ m} = 333\text{ mm}$ **Ans**

•3–69. Determine the angle θ such that an equal force is developed in legs OB and OC. What is the force in each leg if the force is directed along the axis of each leg? The force **F** lies in the $x-y$ plane. The supports at A, B, C can exert forces in either direction along the attached legs.





$$\mathbf{F}_{OA} = F_{OA}\left(-\frac{5}{11.180}\,\mathbf{j} + \frac{10}{11.180}\,\mathbf{k}\right)$$

$$= F_{OA}\,(-0.4472\,\mathbf{j} + 0.89443\,\mathbf{k})$$

$$\mathbf{F}_{OB} = F_{OB}\left(-\frac{5\sin 60^\circ}{11.18}\,\mathbf{i} - \frac{5\cos 60^\circ}{11.18}\,\mathbf{j} - \frac{10}{11.18}\,\mathbf{k}\right)$$

$$= F_{OB}\,(-0.3873\,\mathbf{i} - 0.2236\,\mathbf{j} - 0.8944\,\mathbf{k})$$

$$\mathbf{F}_{OC} = F_{OC}\left(\frac{5\sin 60^\circ}{11.18}\,\mathbf{i} - \frac{5\cos 60^\circ}{11.18}\,\mathbf{j} - \frac{10}{11.18}\,\mathbf{k}\right)$$

$$= F_{OC}\,(0.3873\,\mathbf{i} - 0.2236\,\mathbf{j} - 0.8944\,\mathbf{k})$$

$$\mathbf{F} = 100\,(\sin\theta\,\mathbf{i} + \cos\theta\,\mathbf{j})$$

$\Sigma F_x = 0;\quad -0.3873\,F_{OB} + 0.3873\,F_{OC} + 100\sin\theta = 0$

If $F_{OC} = F_{OB}$, then $100\sin\theta = 0;\quad \theta = 0^\circ$ **Ans**

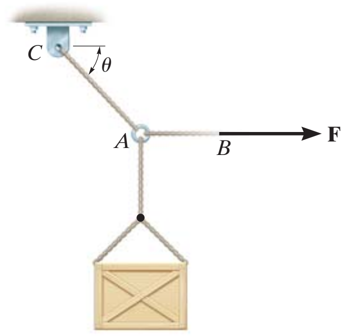
$\Sigma F_y = 0;\quad -0.4472\,F_{OA} - 0.2236\,F_{OB} - 0.2236\,F_{OC} + 100 = 0$

$\Sigma F_z = 0;\quad 0.8944\,F_{OA} - 0.8944\,F_{OB} - 0.8944\,F_{OC} = 0$

$F_{OA} = 149\text{ lb}$ **Ans**

$F_{OB} = F_{OC} = 74.5\text{ lb}$ **Ans**

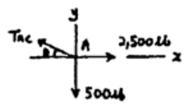
3–70. The 500-lb crate is hoisted using the ropes AB and AC. Each rope can withstand a maximum tension of 2500 lb before it breaks. If AB always remains horizontal, determine the smallest angle θ to which the crate can be hoisted.



Case 1 : Assume $T_{AB} = 2500$ lb

$\xrightarrow{+} \Sigma F_x = 0; \quad 2500 - T_{AC} \cos\theta = 0$

$+\uparrow \Sigma F_y = 0; \quad T_{AC} \sin\theta - 500 = 0$



Solving,

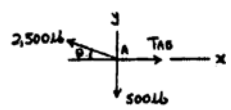
$\theta = 11.31°$

$T_{AC} = 2549.5 \text{ lb} > 2500 \text{ lb}$ (N.G!)

Case 2 : Assume $T_{AC} = 2500$ lb

$+\uparrow \Sigma F_y = 0; \quad 2500 \sin\theta - 500 = 0$

$\theta = 11.54°$

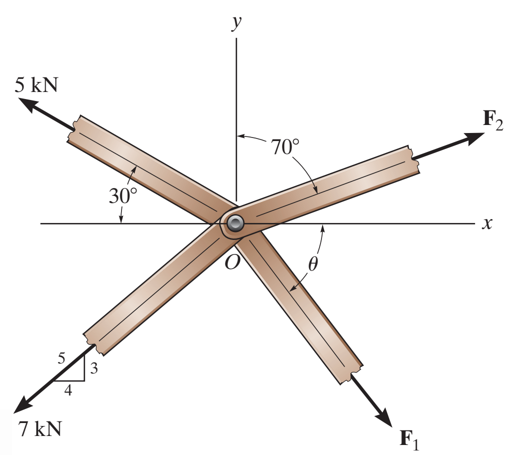


$\xrightarrow{+} \Sigma F_x = 0; \quad T_{AB} - 2500 \cos 11.54° = 0$

$T_{AB} = 2449.49 \text{ lb} < 2500 \text{ lb}$

Thus, the smallest angle is $\theta = 11.5°$ **Ans**

3–71. The members of a truss are pin connected at joint O. Determine the magnitude of $\mathbf{F}_1$ and its angle θ for equilibrium. Set $F_2 = 6$ kN.

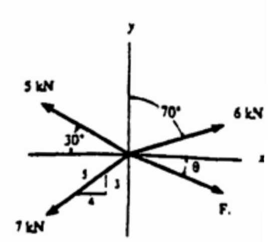


$\xrightarrow{+} \Sigma F_x = 0; \quad 6 \sin 70° + F_1 \cos\theta - 5 \cos 30° - \frac{4}{5}(7) = 0$

$F_1 \cos\theta = 4.2920$

$+\uparrow \Sigma F_y = 0; \quad 6 \cos 70° + 5 \sin 30° - F_1 \sin\theta - \frac{3}{5}(7) = 0$

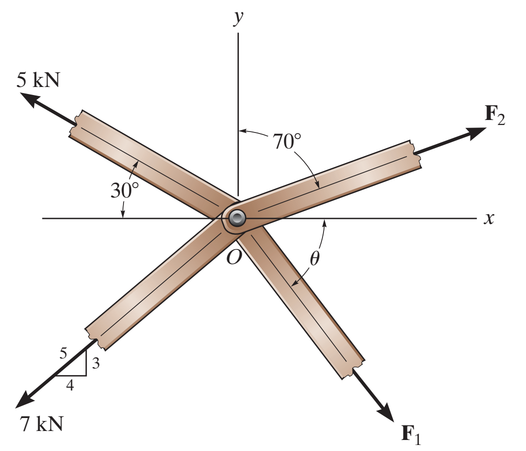
$F_1 \sin\theta = 0.3521$



Solving:

$\theta = 4.69°$ **Ans** $\quad F_1 = 4.31$ kN **Ans**

***3–72.** The members of a truss are pin connected at joint O. Determine the magnitudes of $\mathbf{F}_1$ and $\mathbf{F}_2$ for equilibrium. Set $\theta = 60^\circ$.

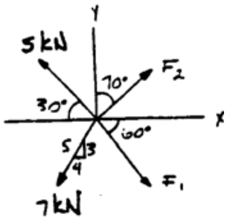


$\xrightarrow{+} \Sigma F_x = 0;\quad F_2 \sin 70^\circ + F_1 \cos 60^\circ - 5\cos 30^\circ - \frac{4}{5}(7) = 0$

$0.9397F_2 + 0.5F_1 = 9.930$

$+\uparrow \Sigma F_y = 0;\quad F_2 \cos 70^\circ + 5\sin 30^\circ - F_1 \sin 60^\circ - \frac{3}{5}(7) = 0$

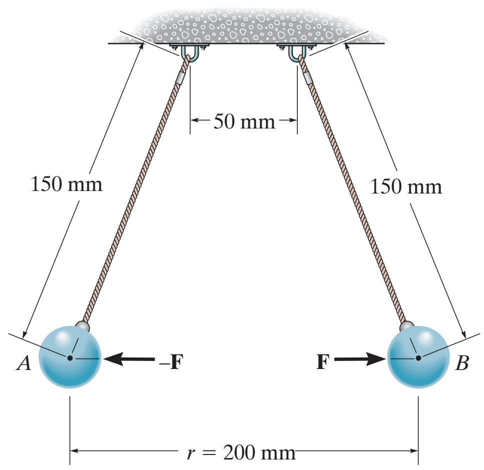
$0.3420F_2 - 0.8660F_1 = 1.7$

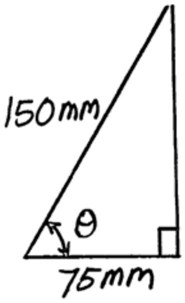


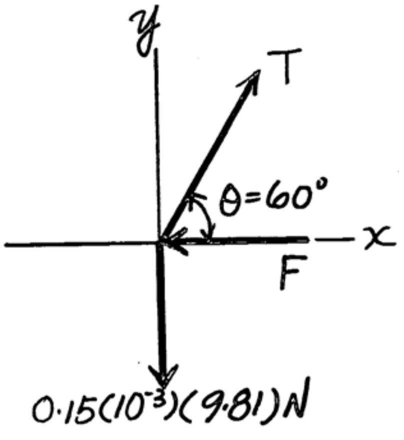
Solving:

$F_2 = 9.60$ kN **Ans** $\qquad F_1 = 1.83$ kN **Ans**

•3–73. Two electrically charged pith balls, each having a mass of 0.15 g, are suspended from light threads of equal length. Determine the magnitude of the horizontal repulsive force, F, acting on each ball if the measured distance between them is $r = 200$ mm.







$$\cos\theta = \frac{75}{150} \qquad \theta = 60^\circ$$

$+\uparrow \Sigma F_y = 0;\quad T\sin 60^\circ - 0.15(10)^{-3}(9.81) = 0$

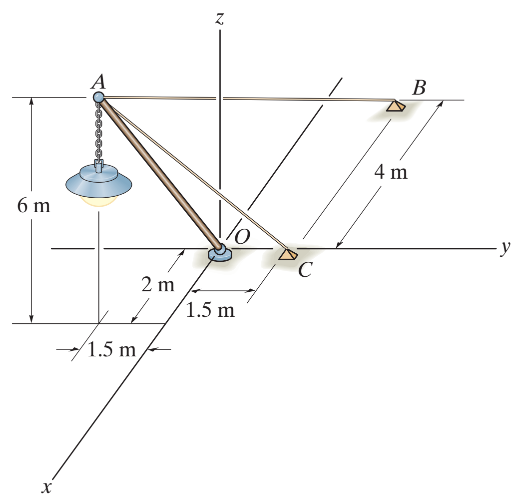
$$T = 1.699(10)^{-3}\ \text{N}$$

$\xrightarrow{+} \Sigma F_x = 0;\quad 1.699(10)^{-3}\cos 60^\circ - F = 0$

$$F = 0.850(10)^{-3}\ \text{N}$$

$$= 0.850\ \text{mN} \qquad \textbf{Ans}$$

3–74. The lamp has a mass of 15 kg and is supported by a pole AO and cables AB and AC. If the force in the pole acts along its axis, determine the forces in AO, AB, and AC for equilibrium.



Cartesian Vector Notation :

$$\mathbf{F}_{AB} = F_{AB}\left(\frac{-6\mathbf{i}+3\mathbf{j}-6\mathbf{k}}{\sqrt{(-6)^2+3^2+(-6)^2}}\right) = -\frac{2}{3}F_{AB}\mathbf{i}+\frac{1}{3}F_{AB}\mathbf{j}-\frac{2}{3}F_{AB}\mathbf{k}$$

$$\mathbf{F}_{AC} = F_{AC}\left(\frac{-2\mathbf{i}+3\mathbf{j}-6\mathbf{k}}{\sqrt{(-2)^2+3^2+(-6)^2}}\right) = -\frac{2}{7}F_{AC}\mathbf{i}+\frac{3}{7}F_{AC}\mathbf{j}-\frac{6}{7}F_{AC}\mathbf{k}$$

$$\mathbf{F}_{AO} = F_{AO}\left(\frac{2\mathbf{i}-1.5\mathbf{j}+6\mathbf{k}}{\sqrt{2^2+(-1.5)^2+6^2}}\right) = \frac{4}{13}F_{AO}\mathbf{i}-\frac{3}{13}F_{AO}\mathbf{j}+\frac{12}{13}F_{AO}\mathbf{k}$$

$$\mathbf{F} = \{-147.15\mathbf{k}\}\ \text{N}$$

Equations of Equilibrium :

$$\Sigma\mathbf{F} = 0; \quad \mathbf{F}_{AB}+\mathbf{F}_{AC}+\mathbf{F}_{AO}+\mathbf{F} = \mathbf{0}$$

$$\left(-\frac{2}{3}F_{AB}-\frac{2}{7}F_{AC}+\frac{4}{13}F_{AO}\right)\mathbf{i}+\left(\frac{1}{3}F_{AB}+\frac{3}{7}F_{AC}-\frac{3}{13}F_{AO}\right)\mathbf{j}$$
$$+\left(-\frac{2}{3}F_{AB}-\frac{6}{7}F_{AC}+\frac{12}{13}F_{AO}-147.15\right)\mathbf{k} = \mathbf{0}$$

Equating i, j and k components, we have

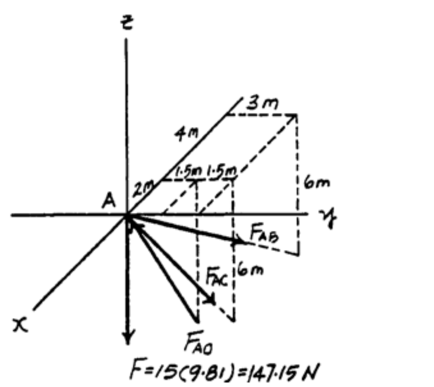
$$-\frac{2}{3}F_{AB}-\frac{2}{7}F_{AC}+\frac{4}{13}F_{AO} = 0 \qquad [1]$$

$$\frac{1}{3}F_{AB}+\frac{3}{7}F_{AC}-\frac{3}{13}F_{AO} = 0 \qquad [2]$$

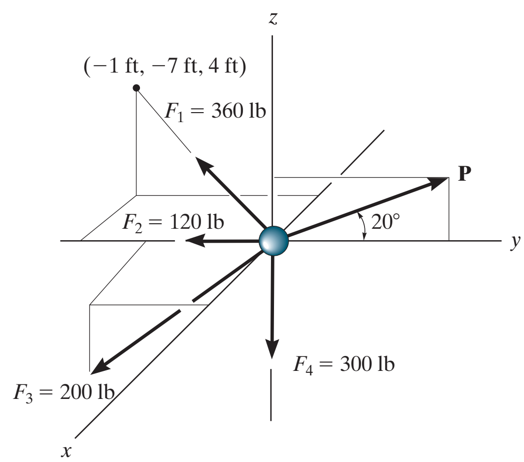
$$-\frac{2}{3}F_{AB}-\frac{6}{7}F_{AC}+\frac{12}{13}F_{AO}-147.15 = 0 \qquad [3]$$

Solving Eqs. [1], [2] and [3] yields

$F_{AB} = 110$ N $\quad F_{AC} = 85.8$ N $\quad F_{AO} = 319$ N **Ans**

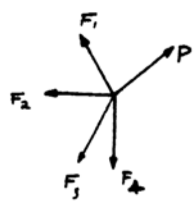


3–75. Determine the magnitude of **P** and the coordinate direction angles of $\mathbf{F}_3$ required for equilibrium of the particle. Note that $\mathbf{F}_3$ acts in the octant shown.



$$\mathbf{F}_1 = 360\left(-\frac{1}{\sqrt{66}}\mathbf{i} - \frac{7}{\sqrt{66}}\mathbf{j} + \frac{4}{\sqrt{66}}\mathbf{k}\right)$$

$$= -44.313\,\mathbf{i} - 310.191\,\mathbf{j} + 177.252\,\mathbf{k}$$



$$\mathbf{F}_2 = -120\,\mathbf{j}$$

$$\mathbf{F}_4 = -300\,\mathbf{k}$$

$$\mathbf{F}_3 = F_x\,\mathbf{i} + F_y\,\mathbf{j} + F_z\,\mathbf{k} \qquad (1)$$

$$\mathbf{P} = P\cos 20^\circ\,\mathbf{j} + P\sin 20^\circ\,\mathbf{k}$$

$\Sigma F_x = 0;\quad -44.313 + F_x = 0$

$F_x = 44.313$ lb

$\Sigma F_y = 0;\quad -310.191 - 120 + F_y + 0.9397\,P = 0$

$\Sigma F_z = 0;\quad 177.252 - 300 + F_z + 0.3420\,P = 0$

From Eq. (1), require

$$200 = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

$$(200)^2 = (44.313)^2 + (430.191 - 0.9397P)^2 + (122.748 - 0.3420P)^2$$

$$P^2 - 892.459P + 162\,095 = 0$$

Solving,

$P = 638.65$ lb and $P = 253.81$ lb

Thus, with $P = 638.65$ lb, $F_y = -169.95$ lb.
With $P = 253.81$ lb, $F_y = 191.69$ lb.
In order for F_3 to be within the octant shown, choose

$P = 639$ lb **Ans**

so that

$F_z = -95.672$

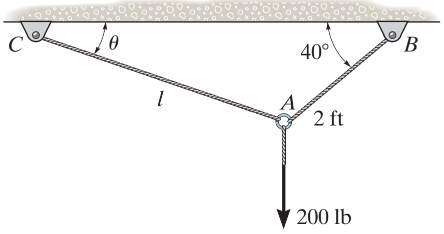
Thus, the direction of F_3 is :

$$\alpha_3 = \cos^{-1}\left(\frac{44.313}{200}\right) = 77.2^\circ \qquad \textbf{Ans}$$

$$\beta_3 = \cos^{-1}\left(\frac{-169.95}{200}\right) = 148^\circ \qquad \textbf{Ans}$$

$$\gamma_3 = \cos^{-1}\left(\frac{-95.672}{200}\right) = 119^\circ \qquad \textbf{Ans}$$

***3–76.** The ring of negligible size is subjected to a vertical force of 200 lb. Determine the longest length l of cord AC such that the tension acting in AC is 160 lb. Also, what is the force acting in cord AB? *Hint:* Use the equilibrium condition to determine the required angle θ for attachment, then determine l using trigonometry applied to ΔABC.



Equations of Equilibrium :

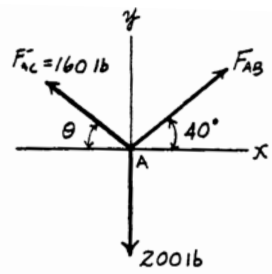
$\xrightarrow{+} \Sigma F_x = 0;\quad F_{AB}\cos 40° - 160\cos\theta = 0$ [1]

$+\uparrow \Sigma F_y = 0;\quad F_{AB}\sin 40° + 160\sin\theta - 200 = 0$ [2]

Solving Eqs.[1] and [2] yields

$\theta = 33.25°$

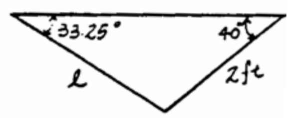
$F_{AB} = 175$ lb **Ans**



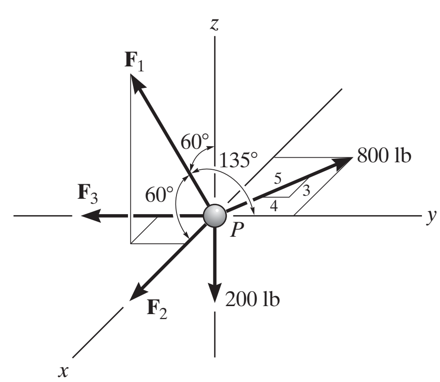
Geometry : Applying law of sines, we have

$$\frac{l}{\sin 40°} = \frac{2}{\sin 33.25°}$$

$l = 2.34$ ft **Ans**



•3–77. Determine the magnitudes of $\mathbf{F}_1$, $\mathbf{F}_2$, and $\mathbf{F}_3$ for equilibrium of the particle.



$\Sigma F_x = 0;\quad F_2 + F_1\cos 60° - 800\left(\frac{3}{5}\right) = 0$

$\Sigma F_y = 0;\quad 800\left(\frac{4}{5}\right) + F_1\cos 135° - F_3 = 0$

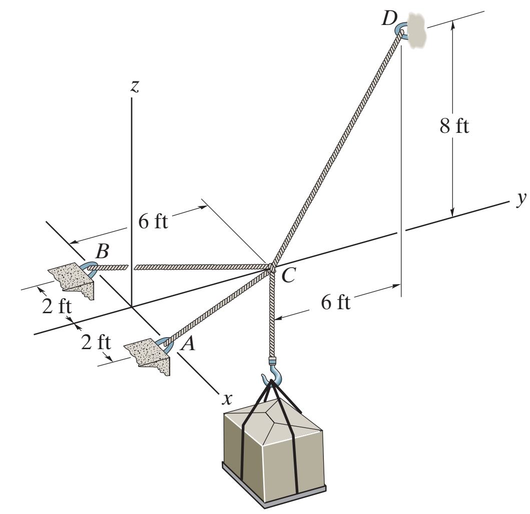
$\Sigma F_z = 0;\quad F_1\cos 60° - 200 = 0$

$F_1 = 400$ lb **Ans**

$F_2 = 280$ lb **Ans**

$F_3 = 357$ lb **Ans**

3–78. Determine the force in each cable needed to support the 500-lb load.



Equation of Equilibrium :

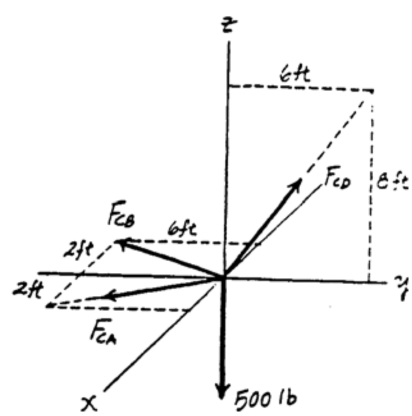
$\Sigma F_z = 0;\quad F_{CD}\left(\frac{4}{5}\right) - 500 = 0 \qquad F_{CD} = 625\ \text{lb}$ **Ans**

Using the results $F_{CD} = 625$ lb and then summing forces along x and y axes we have

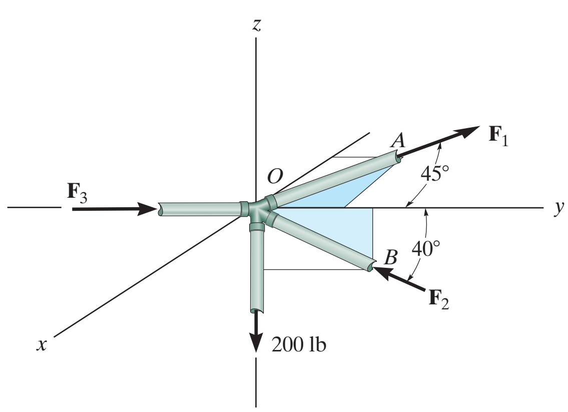
$\Sigma F_x = 0;\quad F_{CA}\left(\frac{2}{\sqrt{40}}\right) - F_{CB}\left(\frac{2}{\sqrt{40}}\right) = 0 \qquad F_{CA} = F_{CB} = F$

$\Sigma F_y = 0;\quad 2F\left(\frac{6}{\sqrt{40}}\right) - 625\left(\frac{3}{5}\right) = 0$

$F_{CA} = F_{CB} = F = 198\ \text{lb}$ **Ans**



3–79. The joint of a space frame is subjected to four member forces. Member OA lies in the x–y plane and member OB lies in the y–z plane. Determine the forces acting in each of the members required for equilibrium of the joint.



Equation of Equilibrium :

$\Sigma F_x = 0;\quad F_1 \sin 45° = 0 \qquad F_1 = 0$ **Ans**

$\Sigma F_z = 0;\quad F_2 \sin 40° - 200 = 0 \qquad F_2 = 311.14\ \text{lb} = 311\ \text{lb}$ **Ans**

Using the results $F_1 = 0$ and $F_2 = 311.14$ lb and then summing forces along the y axis, we have

$\Sigma F_y = 0;\quad F_3 - 311.14\cos 40° = 0 \qquad F_3 = 238\ \text{lb}$ **Ans**